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Special Articles

Separate Digestion—Walraven

Kitchener Plant—Gore

Mechanical Equipment—Ayer

[illegible] of Sewage Sludge—[illegible]

[illegible] of Oil Refinery Wastes—[illegible]

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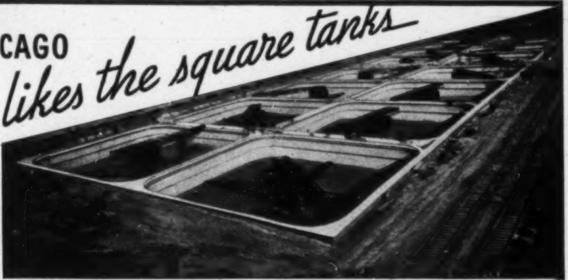

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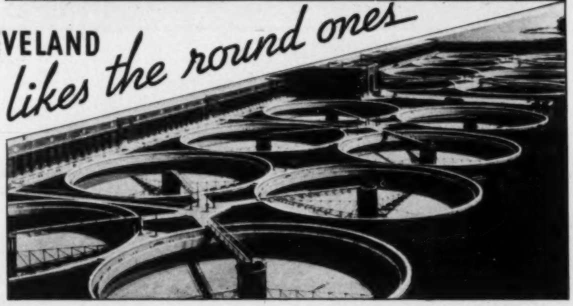

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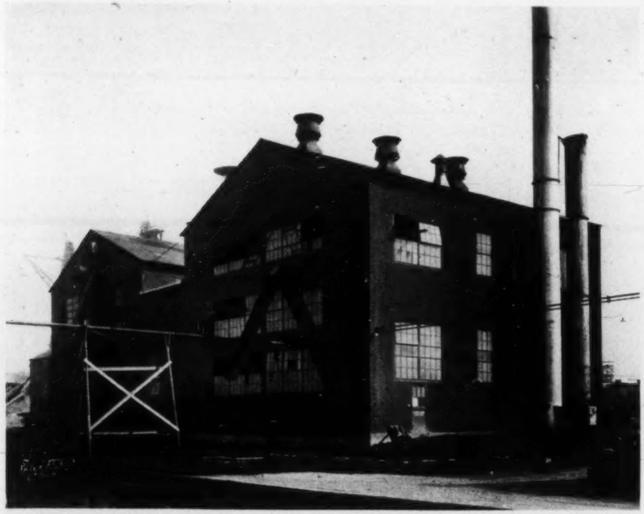

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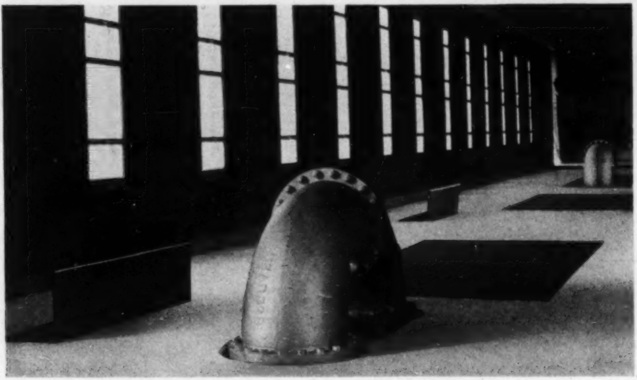

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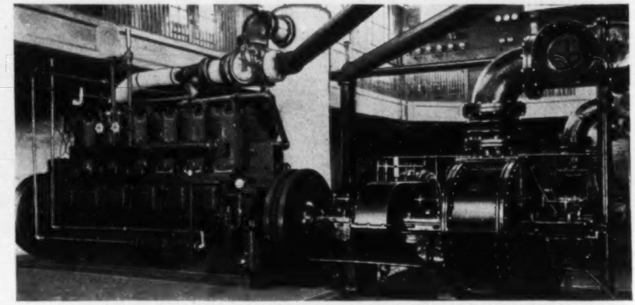

Installation of Clark engine connected to blower at Springfield, Ill., Sanitary District Plant. W. B. Walraven, District Engineer

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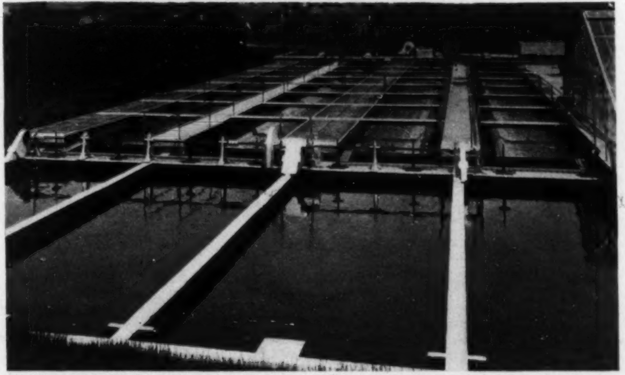

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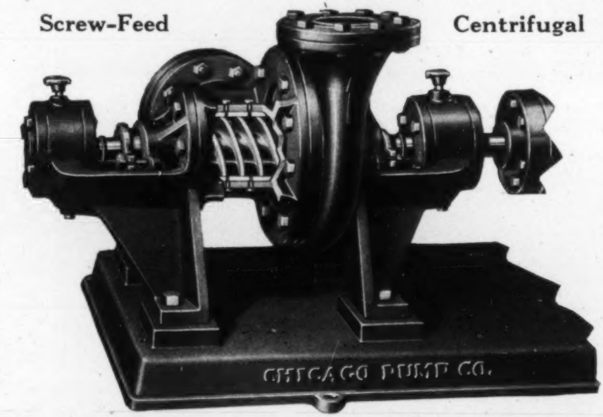

Fig. 1860.—The Chicago "Scru-Peller" Sludge Pump which was designed especially for pumping Primary Sludge. The casing has been cut away in this picture to show the screw conveyor in the suction ahead of the impeller. The capacity can be varied instantly from maximum of the pump all the way down to 1 G.P.M.

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Sewage Research

DIGESTION OF MIXTURES OF SLUDGE FROM DOMESTIC SEWAGE AND PACKINGHOUSE WASTES *

By O. J. Knechtges, Francis M. Dawson and M. Starr Nichols

For cities in which packinghouse waste comprises a part of the sewage treatment problem, the disposal of the two sludges presents a problem of major importance. Can the packinghouse sludge be handled more efficiently separately or mixed with sewage sludge? This work was undertaken because such a problem confronted the City of Madison and is likely to be encountered at other packing centers.

The average values for the analytical components of the two sludges as produced in the raw condition at Madison are given in Table I.

Table I

	Fresh Domestic Sludge	Oscar Mayer Packinghouse Sludge
	(Results in Grams per	Liter of Sludge)
Total Solids	35.00	53.00
Volatile Solids	25.00	38.00
Organic Nitrogen	1.1	2.67
Nitrogen as Free Ammonia	0.238	0.650
Lipids (Chloroform Extractives)	12.0	13.2

Experimental

The series of experiments here reported comprise twenty-six separate batch digestions of plain and mixed domestic sewage and packinghouse waste sludges. Twenty-one of these digests were seeded with ripe sludge from previous batch digestion experiments. The remaining five digests were begun with fresh sludges. These digestions were made in ordinary five-gallon bottles. Each bottle was perforated near the bottom and equipped with a tube of large bore for withdrawing sludge samples. The opening at the top was connected to a gas collection bottle. The gas evolved during digestion was collected over water. Each bottle was charged with approximately thirteen liters of sludge at the beginning of the digestion period. This amount of sludge allowed adequate space above for gasification and for agitating the sludge

---

* From the Department of Hydraulic and Sanitary Engineering and Wisconsin State Laboratory of Hygiene, University of Wisconsin, Madison, Wisconsin.

each time samples of sludge were withdrawn for analysis. The arrangement of the experimental equipment is shown in the accompaning photograph. Temperature was maintained constant at 25° C. by a closed air circulating system, thermostatically controlled.

Nine of these experiments covered a period of 130 days and consisted of nine separate digests. Seven of these bottles contained mixtures of the two sludges, domestic sewage sludge (D) and packinghouse waste sludge (P) mixed in varying proportions of each as follows: 1 P : 8 D, 1 P : 4 D, 1 P : 2 D, 1 P : 1 D, 2 P : 1 D, 4 P : 1 D, 8 P : 1 D, and in addition two other bottles, one containing sludge from domestic sewage and the other from packinghouse waste. These two latter bottles served as controls. Each of these nine digests was seeded with 10 per cent of its volume of ripe sludge of the same proportions used in previous digestion experiments. In another series of experiments five bottles, designated A, B, C, D, and E, containing plain and mixed fresh sludges without seeding, were submitted to digestion in a similar manner.

Data were obtained at frequent intervals on the rate of gasification, changes in pH values, total and volatile solids losses, ammonia and organic nitrogen conservation, and carbon dioxide content of gas evolved. In all these series of experiments, complete digestion was considered to have taken place when gas production had receded practically to zero and remained so after a period of very active gasification.

Total Solids.—In Tables II and IIA are shown the time in days for digestion to be completed and the amount of solids converted to gas during the period of digestion. In the former the sludges were seeded with 10 per cent ripe sludges and in the latter no seedings of the fresh sludge mixtures were made.

The results shown in Column 3 of Table II represent the solids remaining after the number of days of digestion as shown in Column 6. The amount of solids converted to gas, as shown in Column 4, divided by the number of days as shown in Column 6, gives the average amount of solids converted to gas each day, expressed in milligrams per liter of liquid sludge. In this series of experiments the amount of solids digested in a given space per day was lowest when the sludge was either plain domestic (Bottle 1) or a low proportion of packinghouse to domestic (Bottle 2). The most rapid digestion of solids on this weight basis was shown in Bottle 8, which contained a high proportion of packinghouse to domestic, four time the rate of Bottle 1 and nearly three times the rate of Bottle 2. The other mixtures, Bottles 3, 4, 5, 6, and 9 showed rather uniform rates. Bottle 7 (4 P : 1 D) showed a slightly higher rate and its contents more nearly approached the mixture of Bottle 8 than any of the others. The general trend of these

TABLE II.—*Total Solids**

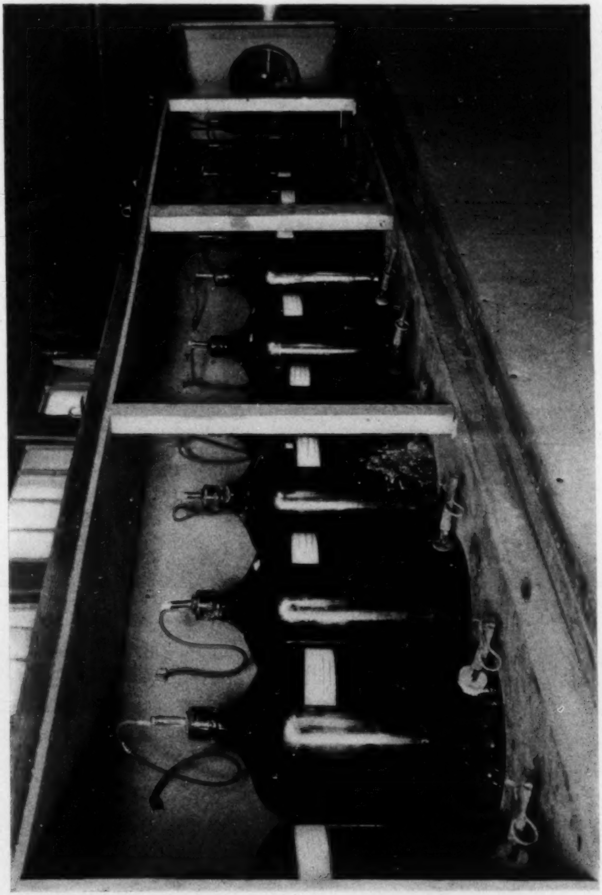
Bottle Number	1 Proportions of Sludges in Mixtures in Bottles D = Domestic P = Packinghouse	Grams of Total Solids per 1000 c.c. of Liquid Sludge			5 Percentage of Original Total Solids Gasified	6 Time Required for Digestion to be Completed, Days	7 Milligrams of Solids Converted to Gas per Liter of Sludge per Day
		2 Present at the Beginning of the Digestion Period	3 Remaining in Ripe Sludge at End of the Digestion Period	4 Converted to Gas			
1	Domestic	34.7	26.0	8.7	25 1	130.	67.
2	1 P : 8 D	35.6	26.2	9.4	26.4	100.	94.
3	1 P : 4 D	38.0	25.6	12.4	32.6	81.	153.
4	1 P : 2 D	39.7	27.8	11.9	30.0	81.	147.
5	1 P : 1 D	40.9	27.6	13.3	32.5	85.	153.
6	2 P : 1 D	42.2	29.9	12.3	29.1	85.	145.
7	4 P : 1 D	45.9	32.4	13.5	29.4	75.	180.
8	8 P : 1 D	49.4	32.7	16.7	33.8	65.	257.
9	Packinghouse	52.9	38.5	14.4	27.3	96.	150.

* Digests seeded with 10 per cent ripe sludges.

TABLE II A.—*Total Solids* *

Bottle Letter	1 Proportions of Sludges in Mixtures in Bottles P = Packinghouse D = Domestic	Grams of Total Solids in 1000 c.c. of Liquid Sludge			5 Percentage of Original Total Solids Gasified	6 Time Required for Digestion to be Complete, Days	7 Milligrams of Solids Converted to Gas per Liter of Sludge per Day
		2 Fresh	3 Ripe	4 Changed to Gas			
A	Domestic	29.3	21.5	7.8	26.6	80.	97.
B	2 D to 1 P	36.4	22.6	13.8	38.0	88.	157.
C	1 D to 1 P	39.9	25.8	14.1	36.2	93.	152.
D	1 D to 4 P	46.3	33.6	12.7	27.4	80.	159.
E	Packinghouse	50.5	32.4	18.1	35.8	93.	195.

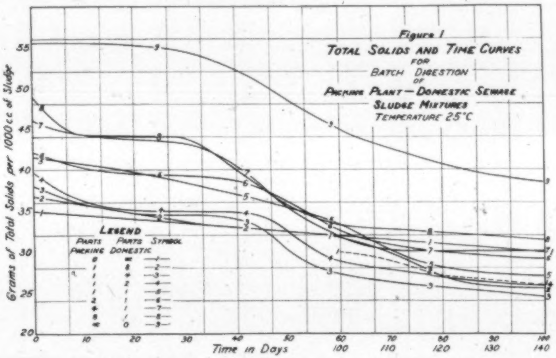
* Digests were not seeded.



Laboratory set-up for sludge digestion experiments on plain and mixed domestic sewage and packinghouse wastes.

digestions can be gained by referring to Fig. 1, in which the curves show the disappearance of the solids in relation to time of digestion.

In Table IIA, Column 7 the values for daily digestion of solids follow very closely the data given for seeded sludge. The amount digested daily in Bottle A of this series for plain domestic sludge exceeded greatly the amount given for Bottle 1 of the seeded series. With this unseeded series the percentage of fresh sludges digested were also slightly greater. These small differences, however, should not be considered too significant because they may be due only to normal variations in sludge quality and composition.



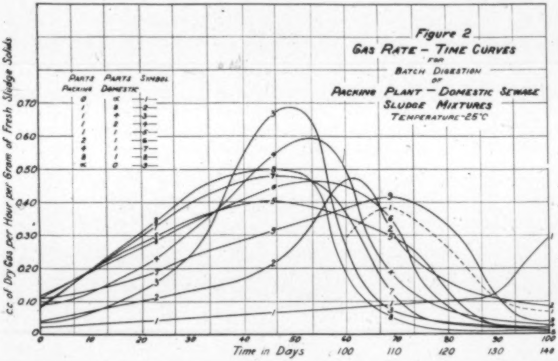
In Table IIB are given the results showing the influence of large proportions of ripe sludge upon the time for the completion of gasification. These results were obtained from observation of the rate of gasification in twelve digests and are compared with the five digests A, B, C, D, and E as the unseeded controls.

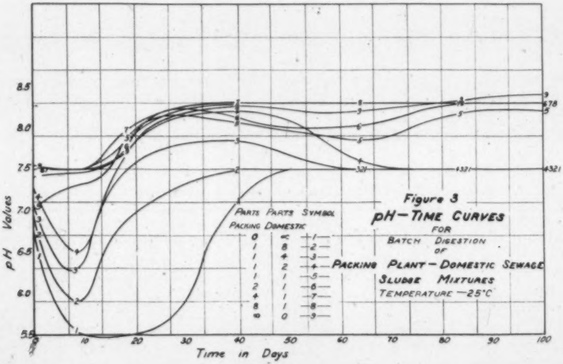
Table II B

Ratio of Fresh Sludge to Ripe Sludge by Volume	Time to Complete Digestion (Days to End of Active Gasification Period) D = Domestic P = Packinghouse				
	Domestic	2 D to 1 P	1 D to 1 P	1 D to 4 P	Packinghouse
Fresh Only	(A) 80	(B) 88	(C) 93	(D) 80	(E) 93
2 Fresh to 1 Ripe		70	40	70	60
1 Fresh to 1 Ripe		30	37	60	47
1 Fresh to 2 Ripe		25	20	53	40

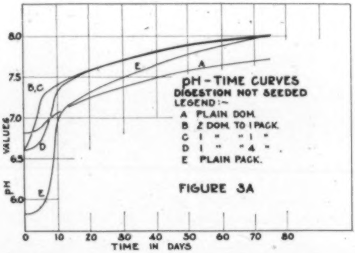
While it appears from this table that seeding with large proportions of ripe sludges causes digestion, as measured by gasification, to be completed in a shorter time, however, the volume of raw sludge handled per unit of space per unit time is not increased by these heavy seedings.

Gasification and pH.—In Fig. 2 are shown the rates of gasification for each of the nine seeded bottles over the entire period of the digestion. From the curve for Bottle 1, plain domestic sludge, there is seen to be a lag for the first 70 or 80 days of the digestion period, after which gasification passes through the normal peak similar to the other sludges. This lag was accompanied by a decided drop in pH as will be seen from Fig. 3, Curve 1. It is interesting to note in this connection that gasifica-

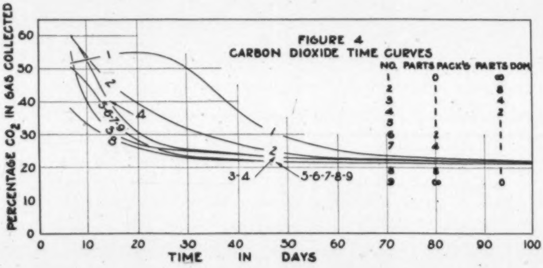




tion was delayed for nearly 40 days after the acid phase had disappeared. Bottles 2, 3, and 4, with low packinghouse sludge ratios, also showed a dip toward the acid phase, as seen by the pH curves of Fig. 3, but not of sufficient extent as to interfere with the apparently normal gasification (Fig. 2), although gasification was somewhat delayed in Bottle 2. From Fig. 3 it should be noted that in Bottles 5, 6, 7, 8 and 9, in which the packinghouse sludge comprised at least 50 per cent of the digest, this sludge seemed either to act as a buffer because of its relatively high organic nitrogen content, or through neutralization of the acid components by the liberation of free ammonia by hydrolysis of the organic nitrogen bodies. In the series of bottles which received no seeding sludge there appeared no lag period, neither did there occur any drop in pH from the beginning value. The pH curves for this series are given in Fig. 3a.



Gas analysis (for carbon dioxide content) during the period of digestion showed some marked variations. From the curves shown in Fig. 4 carbon dioxide comprised from 40 to 60 per cent of the gas liberated at the beginning of gasification. With the exception of Bottles 1 and 2, in which domestic sludge was present alone or in great preponderance,



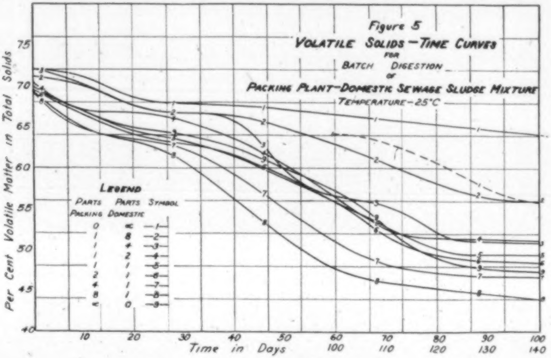
the percentage of carbon dioxide dropped rapidly until at the end of the first twenty days it had reached 30 per cent and soon became quite constant between 22 and 25 per cent. If these carbon dioxide curves are superimposed on the gas-rate curves shown in Fig. 2, it will readily be seen that the volume of gas of high CO_2 content will amount to something less than 10 per cent of the total gas produced. The bulk of the gas produced ranged from 22 to 25 per cent carbon dioxide, with a probable overall average of about 23 per cent. Table III gives the average of eleven representative total gas analyses made on gas evolved at about the 75th day of gasification from the various mixtures of seeded packinghouse waste and domestic sewage sludge digests. The absence of nitrogen in the gas evolved, as shown by these analyses, is not in accordance with the usual experience of sewage plant operators. The nitrogen encountered in the gas from continuous sludge digestion in plant practice is evidently derived from the atmospheric nitrogen carried by the daily additions of fresh sludge to the digesting mixture. Our digests received no added sludge from the start and the gas analyzed was collected after all atmospheric nitrogen had been swept out of the bottles. The organic and ammonia nitrogen conservation shown in Tables IV and IVA also support our gas findings.

TABLE III

	Maximum	Minimum	Average
Carbon Dioxide	25.6	20.2	23.2
Oxygen	0.9	0.0	0.1
Methane	79.8	71.6	76.7
Hydrogen	3.0	0.3	1.1

The carbon dioxide time curves were constructed from gas analyses made about five days apart on gas evolved from each of the nine seeded digests—about 150 determinations in all.

Volatile Solids.—The reduction of volatile solids followed very closely that of total solids. In Fig. 5 are shown curves for the percentage volatile matter in the total solids. Curves representing mixed digests which contained much packinghouse sludge showed the greatest loss in volatile solids. It will also be noted that the percentage volatile matter in the ripe sludge reached its lowest value in Bottle 8, which contained 8 parts of packinghouse to 1 part domestic sludge. Digests in Bottles 7, 6, 5, 4 and 3 show final percentages of reduction in proportion to the ratio of packinghouse to domestic sludge. From a starting point of between 69 and 72 per cent volatile matter in the fresh sludges there develops a divergence of between 44 and 56 per cent in the ripe sludge.



Apparently the admixture of the packinghouse waste sludge with the domestic sludge influenced the digestion in a desirable direction.

Ammonia and Organic Nitrogen.—In Table IV for the seeded, and in Table IVA for the unseeded digests, are given the changes in organic and ammonia nitrogen during the course of digestion for the separate sludges and sludge mixtures.

TABLE IV

Bottle Number	Bottle Contents	Nitrogen in Parts per Million in Liquid Sludge †					
		Organic Nitrogen			Ammonia Nitrogen		
	Mixture	Fresh	Ripe 100 da.	Loss	Fresh	Ripe 100 da.	Gain
1	D only	1100.	799.	301.	238.	598.	360.
2	1 P : 8 D	1350.	881.	469.	225.	831.	606.
3	1 P : 4 D	1400.	843.	557.	375.	917.	542.
4	1 P : 2 D	1665.	799.	866.	275.	1145.	870.
5	1 P : 1 D	1803.	856.*	947.	350.	1405.	1055.
6	2 P : 1 D	1945.	896.*	1049.	375.	1695.	1320.
7	4 P : 1 D	2098.	919.	1179.	525.	1785.	1260.
8	8 P : 1 D	2125.	867.	1258.	550.	1951.	1401.
9	P only	2667.	1135.	1532.	650.	2306.	1656.

* 85 day result. 100 day analysis not done.

† Digests seeded with 10 per cent ripe sludges.

TABLE IV A.—*Free Ammonia and Organic Nitrogen*

Bottle Number	1 Proportions of Sludges in Mixtures in Bottles P = Packinghouse D = Domestic	Nitrogen in Parts per Million in the Liquid Sludge *					
		Organic Nitrogen			Free Ammonia Nitrogen		
		2 Fresh	3 Ripe	4 Loss	5 Fresh	6 Ripe	7 Gain
A	Domestic	950.	595.	355.	145.	460.	315.
B	2 D to 1 P	1253.	593.	650.	288.	918.	630.
C	1 D to 1 P	1500.	655.	845.	363.	1078.	715.
D	1 D to 4 P	1920.	783.	1137.	530.	1425.	895.
E	Packinghouse	1950.	935.	1015.	610.	1550.	940.

* No seeding sludge added.

The results given in Tables IV and IVA are representative of 300 results, which were used to plot the curves shown in Fig. 6 (organic nitrogen) and Fig. 7 (free ammonia nitrogen). While the results shown in these tables do not balance exactly, loss and gain as should be expected are close enough to demonstrate that there is little loss of elemental nitrogen in these batch digestions even though anaerobic conditions prevail during the entire time of digestion. It is interesting to note that in spite of the wide variation in the organic nitrogen content at the beginning of the digestion period the amount of organic nitrogen in the ripe sludge reached a somewhat constant level of between 800

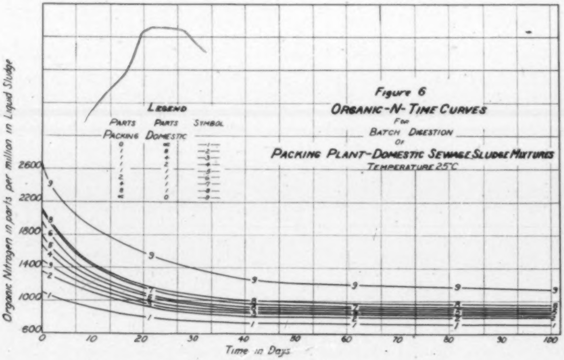
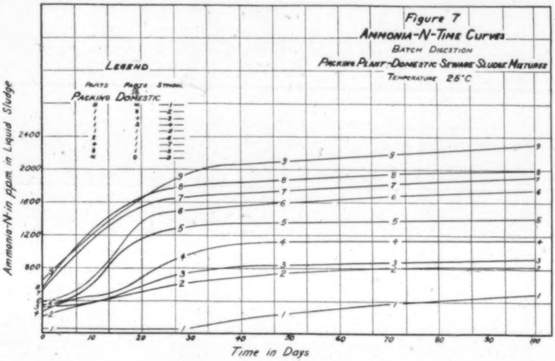


Figure 6
ORGANIC-N-TIME CURVES
FOR
BATCH DIGESTION
OF
PACKING PLANT-DOMESTIC SEWAGE SLUDGE MIXTURES
TEMPERATURE 25°C



and 900 parts per million in the seeded and somewhat lower in the unseeded digests. To reach such a level more organic nitrogen must have been decomposed in those bottles containing increasing proportions of packinghouse sludge.

Of the changes in total organic nitrogen, as evidenced by analyses, 90 per cent of the hydrolysis occurs in the first 40 days of the digestion and not during the peaks of gasification. Hydrolysis and synthesis of nitrogenous bodies probably are balanced during the middle and latter part of the digestion period in such amounts as are necessary for cell structure as gasification of the carbonaceous matter ensues.

Table V.—*Lipids in Sludge*

Bottle Number	Proportions of Sludges in Mixtures in Bottles P = Packinghouse D = Domestic	Lipids in Grams per 1000 c.c. of Liquid Sludge †					
		Ethyl Ether Extract			Chloroform Extract		
		Fresh	End of 56 Days	Loss	Fresh	End of 56 Days	Loss
A	Domestic	9.9	4.9	5.0	10.7	5.5	5.2
B	2 D to 1 P	8.6	4.8	3.8	9.4	3.0	6.4
C	1 D to 1 P	9.9	5.0	4.9	12.2	6.5	5.7
D	1 D to 4 P	9.4	4.8	4.6	11.7	6.4	5.3
E	Packinghouse	10.0	5.7	4.3	12.7	2.9*	9.8

* 100 day result.

† No seeding sludge added.

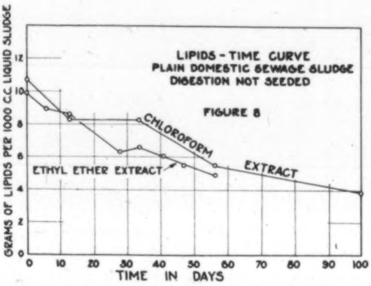
Lipids.—Lipid results were obtained at various intervals of time during the digestion of the five unseeded sludge digests, A, B, C, D, and E. Table V shows the comparative results using both chloroform and ethyl ether as the lipid solvent.

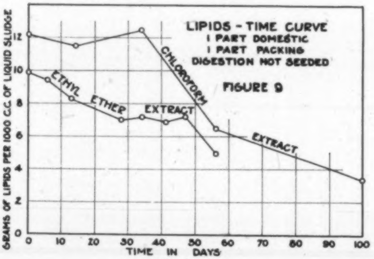
Lipid loss is seen to be about 50 per cent at the end of 56 days for most of the digests. The quantity of lipids as extracted by the two solvents varies considerably. The reason for this variation has been made the subject of a separate study. (See *This Journal,* VI, 1082, Nov., 1934.) In that study the variations in quantity of extractives as obtained from other sludges by the two solvents, ethyl ether and chloroform are greater than those shown in this paper. The curves of Figs. 8, 9 and 10 show the lipids over the course of the digestion of sludges in Bottles A, C, and E. From the beginning of the digestion to the end there is seen to be loss in lipids as measured by chloroform extract of 65 per cent for Digest A (Domestic), 72 per cent for C (1 Domestic to 1 Packinghouse) and 77 per cent for Digest E (Packinghouse). The total solids loss (see Table IIA) for these bottles were 26.6, 36.2, and 35.8 per cent respectively.

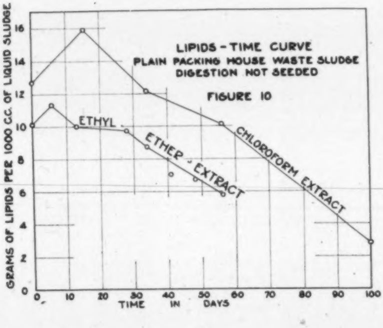
SUMMARY

Plain domestic sewage sludge, packinghouse waste sludge and divers mixtures of each to make a total of 26, five-gallon digests, of about 13 liters each, were submitted to batch digestion. Some of these digests were seeded with 10 per cent ripe sludge, some with 66 per cent and some had no seeding. Some of these bottles were observed for 130 days, the longest time necessary for complete digestion.

Solids losses varied from 25.1 per cent for the 10 per cent seeded domestic sludge digest to 38.0 per cent for a digest not seeded and containing at the start 2 parts by volume of domestic sludge to 1 part of packinghouse. The fastest rate of digestion was obtained in a mixture containing 8 parts of packinghouse sludge to 1 part of domestic, seeded with 10 per cent of ripe sludge of the same proportions. In this digest 257 milligrams of dry solids per liter of liquid sludge was digested to gas daily. Plain packinghouse sludge, not seeded, showed 195 milligrams loss per liter of liquid sludge per day. Plain domestic sludge, seeded with 10 per cent ripe sludge, showed slowest digestion as measured by daily loss of solids per liter of liquid sludge. Gas analysis showed the initial gas to contain more than 50 per cent CO_2 by volume, but the proportion fell rapidly to about 25 per cent before 10 per cent of total gas was evolved. Average gas consisted of about 23 per cent of carbon dioxide, 1 per cent hydrogen and 76 per cent methane. Nitrogen results show fairly good balance, and from them we feel that very little if any nitrogen gas is formed. Ammonia nitrogen increases rapidly at


LIPIDS - TIME CURVE
PLAIN DOMESTIC SEWAGE SLUDGE
DIGESTION NOT SEEDED
FIGURE 8
CHLOROFORM
EXTRACT
ETHYL ETHER EXTRACT
GRAMS OF LIPIDS PER 1000 C.C. LIQUID SLUDGE
0
2
4
6
8
10
12
0
10
20
30
40
50
60
70
80
90
100
TIME IN DAYS


LIPIDS - TIME CURVE
1 PART DOMESTIC
1 PART PACKING
DIGESTION NOT SEEDED
FIGURE 9
CHLOROFORM
EXTRACT
ETHYL
ETHER
EXTRACT
GRAMS OF LIPIDS PER 1000 C.C. OF LIQUID SLUDGE
0
2
4
6
8
10
12
0
10
20
30
40
50
60
70
80
90
100
TIME IN DAYS


LIPIDS - TIME CURVE
PLAIN PACKING HOUSE WASTE SLUDGE
DIGESTION NOT SEEDED
FIGURE 10
CHLOROFORM EXTRACT
ETHYL
ETHER - EXTRACT
GRAMS OF LIPIDS PER 1000 C.C. OF LIQUID SLUDGE
0
2
4
6
8
10
12
14
16
0
10
20
30
40
50
60
70
80
90
100
TIME IN DAYS

the beginning of the digestion and organic nitrogen decreases in a proportionate manner during the initial stages of all the digests. Each nitrogen result reaches a rather constant value early in the digestion period. Lipids were determined by extraction with both ethyl ether and chloroform, the latter usually giving a much greater amount of lipid material. From 65 to 77 per cent of lipids originally present in the digests were digested to gas.

CONCLUSIONS

1. The admixture of packinghouse and domestic sewage sludges in no way hinders the digestion of either sludge, in fact, many of our results show more rapid decomposition in the mixed digests.
2. The acid phase was not evident in any packinghouse-domestic sludge mixture of more than 50 per cent packinghouse sludge by volume.
3. Lipids digest to gas more completely than the bulk of total solids.

A REVIEW OF ACTIVATED SLUDGE THEORY *

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The practical application of activated sludge has become widespread, as evidenced by the number of plants in operation, but our knowledge of the theory has progressed much more slowly. Although it is known that the purification is due to both physico-chemical and biological reactions, the relative importance of each is still undetermined. Certain protozoa are said to be good indicators of the condition of the sludge but the particular organisms or enzymes active in the purification have not been identified. Whether the absorption of oxygen by sewage occurs only at the free surface of the liquid or whether oxygen is dissolved from the bubbles themselves has long been a subject of discussion. Nevertheless, a large amount of work has been done and it is believed that a review of some of the important theories will be of interest.

The mechanism of the activated sludge process probably involves physico-chemical, enzymic, biological and biochemical reactions. Although, at some time, every one of these phenomena has been used to explain the entire process, it is generally agreed that each plays a part in the operation and that a combination of all is necessary for satisfactory purification.

Parsons and Wilson [1] proposed the theory that the activated sludge process consists of at least three stages:

First—Clarification,
Second—Reactivation or restoration of the powers of clarification,
Third—Nitrification.

A fourth might possibly be reactivation of the special nitrifying sludge. The stages of reactivation and nitrification occur simultaneously and although reactivation is essential for clarification, nitrification may be omitted. All three stages may and usually do take place in the same tank, but sometimes provision is made for reactivation or reaeration of the sludge in a separate unit.

The clarification stage includes the removal of colloidal and suspended matter as well as of some of the substances from true solution. Parsons and Wilson emphasized the physical action, such as absorption or adsorption of impurities by the sludge. Their experiments show that clarification approximately follows the adsorption equation, an indication of the importance of reactivation as a means of renewing active surfaces.

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* Presented at the Sixth Annual Meeting of the New England Sewage Works Association, Providence, R. I., October 15, 1934.

This reactivation need not be a separate operation. They concluded that the real biological work occurs during the second or reaeration stage, when the enzymes are produced, and that the clarification stage represents only a physical or chemical reaction of the enzymes.

A theory covering the removal of colloids by activated sludge was proposed by Baly and discussed by Lumb.[2] This theory depends upon the neutralization of electrical charges on colloids. Sewage colloids in distilled water have an isoelectric point at pH 4.6 and this isoelectric point is shifted upward by increasing concentrations of electrolytes in solution. For example, in a three per cent sodium chloride solution, the isoelectric point is at pH 8.3. The sewage examined by Baly was found to contain electrolyte in solution equivalent in conductivity to 0.17 per cent sodium chloride and its isoelectric point was estimated to be at about pH 6.5. This figure is considered very important because, at a pH value less than 6.5, the sewage colloids will be positively charged and, at a pH more than 6.5, negatively charged. Since most sewages have reactions between pH 7.0 and 8.0, their colloids will be slightly negative. Bacteria are negatively charged and, since sludge contains a large number of bacteria, the floc is strongly negative. Sewage colloids normally possess a weak negative charge. Because of the difference in magnitude of the charges, negative sewage colloids are flocculated on the more negative flocs of activated sludge and an even greater clarification would be expected if the negative charge of the sewage were reduced or even made positive. Acid could be used to reduce the pH to below 6.5. Lumb cited experiments at Halifax, England, to show the advantages of this method for increasing the efficiency of clarification. The optimum condition for purification by activated sludge at Bradford was found to be pH 6.0 to 6.5. Lumb believed that plants in which the pH of the sewage varies from 7.5 to 8.0 are probably not operating at maximum efficiency. This theory does not attempt to explain the removal of substances in true solution by the activated sludge process.

Although a number of investigators have studied the problem, little is known of the actual organisms which take part in the activated sludge process. Buswell and Long[3] found a definite succession or addition of forms in the development of activated sludge from raw sewage. At first, they observed that minute flagellates and ciliates predominated, with a few peritrichs and holotrichs, a characteristic of raw sewage. After a short time, the minute forms decreased and the peritrichs, holotrichs and heterotrichs increased in number, the peritrichs predominating throughout. In other words, there is a progression from the lowest ciliated and flagellated protozoa to the more complex forms, which are not only ciliated or flagellated but also have sharp, pointed setae or bristles for moving and feeding purposes. Then the gelatinous masses of chlamydobacteriaceae and nematodes appeared and finally the matured sludge seemed to be composed largely of zoogloeal masses with frequent colonies of peritrichs and an occasional hypotrich (generally *Euplotes*). About seven or eight days were required for the development of the characteristic fauna and flora of the matured activated sludge. In summarizing, the authors state that activated sludge flocs are composed of a synthetic, gelatinous matrix of *Nostoc* or *Merismopedia* in which the filamentous and unicellular bacteria are imbedded and on which the protozoa and some metazoa crawl and feed. The organisms bring about purification by ingestion and assimilation of the organic matter in the sewage and by its resynthesis into the living material of the flocs. This process changes colloidal and dissolved organic matter so that it will settle out. Buswell and Long's theory of the activated sludge process was chiefly a biological one.

Kolkwitz,[4] who examined activated sludge from the Essen-Rellinghausen plant of the Ruhrverband, found bacteria and protozoa similar to those reported by Buswell and Long.

In a microscopic study of activated sludge, Ardern and Lockett[5] concluded: First, that the different species of protozoa are indicative of the condition of the sludge; second, that under proper conditions of aeration, protozoa have no unfavorable influence on the settling properties of the sludge; third, that from the standpoint of sewage treatment in general, protozoa are not important in purification by activated sludge, although they may aid in the production of a more highly clarified effluent. According to their classification, a poor sludge contained a preponderance of amoebas and flagellates with very few ciliates, whereas a satisfactory sludge contained mostly ciliates with only a few amoebas and flagellates. It is interesting to note that the ciliates are largely bacteria-eaters while the other groups are scavengers and live chiefly on organic matter. Ardern and Lockett also found that domestic sewage was richer in protozoa than sewage containing industrial waste.

The investigations of Harris, Cockburn and Anderson[6] have shown that, at the Shieldhall, Glasgow, sewage treatment plant, raw sewage and diffused air activated sludge were similar in bacterial flora, in that each contained 61 per cent *B. aerogenes* and 38 per cent *B. proteus* types of organisms. In mechanically agitated sludge, the ratio was reversed, that is, 38 per cent *B. aerogenes* and 61 per cent *B. proteus*. Both of these groups are capable of secreting proteolytic enzymes and Harris and his associates believe that biochemical changes in the activated sludge process are caused by enzymic rather than by direct bacterial action. However, the digestion phase of the activated sludge process, which must precede nitrification and final oxidation, is not restricted to these groups of bacteria. Many other types, including the higher bacteria, may be involved. The protozoa changed rapidly, with wide variations in number and type. The presence or absence of protozoa did not seem to increase or decrease the efficiency of fully matured sludge but the quality of the sludge may be judged by their number and kind.

A somewhat different explanation of the biological process has been proposed by Wagner,[7] who concluded from his studies that protozoa are important in the purification of sewage. He found that, although bacteria maintain the clarifying power of the sludge by freeing the floc from adsorbed material, better purification is obtained by a limited number of bacteria, a limitation brought about by the feeding of protozoa on bacteria. This theory is similar to that proposed by Butterfield and Purdy [8] in their study of the biochemical oxygen demand. It also agrees in some respects with Ardern and Lockett's use of protozoa as an indication of the condition of the sludge. These authors believed that a satisfactory sludge contains many ciliates or bacteria-eaters.

Rudolfs [9] found that a definite relationship must be maintained between bacteria and protozoa in order to obtain satisfactory results. Neither a large number of bacteria with relatively small numbers of protozoa nor a large number of protozoa with few bacteria gave maximum purification.

More recently, Eisenberg [10] concluded that the protozoa are found almost exclusively on the surface of the floc and that a special fauna seemed to produce a specific degree of purification. She believed that, from both a qualitative and a quantitative standpoint, protozoön fauna are a good index of the purifying power of activated sludge. Her investigations showed that the load could be doubled and aeration decreased when the walls of an activated sludge tank are covered with slime.

Since purification by the activated sludge process is essentially aerobic in nature, the oxygen requirements of the sludge and the rate of solution of oxygen in water are of fundamental importance.

Harris, Cockburn and Anderson [11] determined that, on reaeration, activated sludge reached a point where the oxygen absorption was nearly constant at 110 p. p. m. per hour. Grant, Hurwitz and Mohlman [12] found that activated sludge required 26.6 p. p. m. of oxygen per hour and that the oxygen consumption varied in proportion to the weight of sludge used and to the volatile content of the sludge. Theriault and McNamee [13] stated that the oxygen demand of mixtures of sewage and activated sludge may exceed 60 p. p. m. per hour. Considering the fact that these determinations were made on sludges differing in activity and in solid content, the results agree reasonably well.

Because the biological activity in the process is dependent upon the supply of dissolved oxygen, the rate at which oxygen can be introduced into and mixed with the liquor is a very important factor. A difference of opinion as to the mechanism of the oxygen absorption still exists. Adeney [14] reported that the aeration is largely due to surface absorption and that agitation, either by compressed air or other mechanical means, increases the oxygen absorption, merely because the surface of the liquid is ruffled. He believed that oxygen, after absorption, does not remain concentrated at the surface, but sinks toward the bottom layers of the water. This "streaming" is caused by the increased density which results from the evaporation and subsequent cooling at the surface layer. Downward "streaming," with the resulting mechanical mixing, was as effective at a depth of 10 feet as at a depth of one or two feet. Adeney also believed that air bubbles do not give up oxygen effectively because films of liquid, acting as envelopes to the air, travel, unbroken, with the bubbles. Each film can dissolve only a minute quantity of oxygen from the bubble.

Practical workers,[15] however, have observed that, in the activated sludge process, better results were obtained with small bubbles than with large ones. To study the solution of oxygen in sewage, Parsons and Wilson [16] used tubes 6.5 and 22.5 feet deep. They worked on a fill and draw basis, with the diffused air system, and carried purification to the nitrification stage. Their conclusions were: First, that the concentration of oxygen was at least as high in the tall tube as in the short one; second, that the purification obtained was practically the same in both tubes; and, third, that the air used per gallon of sewage was much less in the tall tube. Fowler and Chatterje [17] have also shown that the streaming effect produced by bubbles breaking at the surface of the liquid is not the only means of aeration.

Advocates of each theory of aeration have ascertained the rates of solution of oxygen, by experiment. Adeney and Becker [18] determined the rate of absorption through exposed surfaces and Adeney [19] developed a formula by which the maximum rate of solution of oxygen can be calculated for different volumes, degrees of saturation and conditions of the exposed surface, provided that the water is uniformly mixed.

Scouller and Watson [20] concluded that the oxygen requirements of activated sludge are so large that they cannot be satisfied by surface action. As evidence of the solution of oxygen from bubbles, they found that the oxygen absorption per square foot of bubble surface per 24 hours was about three times the amount absorbed through an exposed surface.

SUMMARY

Purification by the activated sludge process probably occurs in at least three stages: clarification; reactivation, and nitrification. The first stage is mainly physico-chemical in nature, although biological action is probably necessary. If the clarification of sewage is caused by adsorption alone, a high concentration of sludge in the aeration tanks would be very desirable and aeration would not be necessary. The present tendency seems to be toward a reduction of solids in the aeration tanks and air is almost always added. The second and third stages are chiefly biological and, although the essential organisms have not been identified, both protozoa and bacteria seem to be important. The presence of ciliates, which is said to be indicative of good sludge, may be important in maintaining a balance between the bacteria and protozoa.

Notwithstanding the theory that activated sludge purification takes place in stages, attempts to divide the process into these definite stages have not been very successful. Satisfactory purification can be obtained by stage operation but the general opinion is, that, by the use of this method, no air is saved, operation is more complicated and increased settling area is required.

The oxygen requirements were found to vary from about 27 to 110 p. p. m. per hour for different sludges. The oxygen consumption varies with the weight of the sludge and its volatile content. It has been demonstrated that oxygen is absorbed from air bubbles as well as at the surface of the liquid.

BIBLIOGRAPHY

1. A. S. Parsons and H. Wilson. *The Surveyor,* **72,** 221, 1927.
2. C. Lumb. *The Surveyor,* **83,** 229, 1933.
3. A. M. Buswell and H. Long. *J. A. W. W. Assn.,* **10,** 2, 1923.
4. Kolkwitz. Kl. Mitt. *Ver. Wasserversorg. Abwasserbeseitig.,* **3,** 70, 1926.
5. E. Ardern and W. T. Lockett. *Ann. Report Manchester Rivers Dept.,* page 40, March 28, 1928.
6. F. W. Harris, T. Cockburn and T. Anderson. *Water Works,* **66,** 24, 1927.
7. G. Wagner. *Reprint from 25th Anniversary of the Danzig Technical School,* 1930.
8. C. T. Butterfield and W. C. Purdy. *Ind. Eng. Chem.,* **23,** 213, 1931.
9. W. Rudolfs. *N. J. Agri. Expt. Station Report,* 1932–1933.
10. Emma Hamburg Eisenberg. *Zentrbl. Bact. II,* Abt., **88,** 200, 1933.
11. F. W. Harris, T. Cockburn and T. Anderson. *Proc. Assn. Managers of Sewage Disposal Works,* page 52, 1926.
12. S. Grant, E. Hurwitz and F. W. Mohlman. *Sew. Works Jour.,* **2,** 228, 1930.
13. E. J. Theriault and P. D. McNamee. *Ind. Eng. Chem.,* **22,** 1330, 1930.
14. W. E. Adeney. *The Surveyor,* **82,** 91, 1932.
15. E. Ardern and W. T. Lockett. *J. S. C. I.,* **23,** 1123.
16. A. S. Parsons and H. Wilson. *The Surveyor,* **72,** 490, 598, 1927.
17. Fowler and Chatterje. *The Surveyor,* **72,** 139, 1927.
18. W. E. Adeney and Becker. *Sci. Proc. Dub. Soc.,* **15,** 31 and 34.
19. W. E. Adeney. *Jour. Roy. San. Inst.,* 1932.
20. W. D. Scouller and W. Watson. *The Surveyor,* **86,** 15, 1934.

A RAPID DETERMINATION OF SUSPENDED SOLIDS IN ACTIVATED SLUDGE BY THE CENTRIFUGE METHOD *

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A rapid solids determination, performed with ease and a minimum expenditure of time would provide an efficient tool for activated sludge plant operators even at the expense of considerable accuracy.

The present method for the suspended solids concentration by the gooch filter requires considerable technic, is tedious, time consuming, and the final results are rarely available before six hours.

In numerous industrial processes, the volume of centrifuged solids serve as a rapid control index. Vermilye (4) mentions that at the Tenafly, N. J., activated sludge plant, the volume of centrifuged solids was utilized as a control measure.

A definite relationship between the weight of solids and the volume they occupy can be made only if the density of the sludges remains the same.

The densities of gravity settled activated sludges vary, hence the "sludge index" (1), (2), (3), (5).

Regardless of whether variations in the structural condition or electrical phenomenon cause differences of density it is feasible that a centrifugal force equal to 40 times that of gravity will destroy most of the density variations and that thereby a correlation between the actual weight of solids to the volume they occupy can be made. Were this possible then:

$$X = K \times \frac{\text{Volume of centrifuged solids}}{\text{Volume of sample}}$$

where $X =$ weight of suspended solids

The purpose of this investigation was to correlate the volume of centrifuged solids with the weight as obtained by the gooch filter method and, necessarily, determine the reliability of each method.

Accuracy of the Gooch Filter Method

The gooch filter method for suspended solids of sewages and effluents consists, according to Standard Methods, of the filtration of a sample through a gooch crucible with vacuum, and subsequently drying and weighing the solids retained. "Not more than 30 mg." of dry solids constitutes a sample and "the error which apparently amounts to more than 10 per cent appears to be due to difficulties in collection of the original sample and in withdrawing the portion of the original sample submitted to filtration."

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* Journal Series Paper, N. J. Agricultural Experiment Station, New Brunswick, N. J., Dept. Water & Sewage Research.

The method adopted by the Department of Water and Sewage Research of the N. J. Agricultural Experiment Station for activated sludge liquors is essentially that of Standard Methods except in the size of sample and period of drying. For activated sludges containing 700 to 3000 p.p.m. suspended solids a 50 ml. sample corresponding to 35 to 150 mgrms. dry solids is measured in a graduate, settled in a 100 ml. beaker for 15 to 30 minutes, and filtered through a tared gooch. The order of filtration is supernatant, solids and finally 10 to 15 ml. wash water. For activated sludges containing over 3000 p.p.m. solids, a 25 ml. sample is taken. The moist solids are dried at 103° C. for 6 to 12 hours.

In order to determine the accuracy of the above method the results were compared with a similar method in which the volume of sample was increased for the purpose of decreasing the sampling error. The detailed procedure consisted of settling one liter samples of activated sludge mixtures for one hour (suspended solids from 1000 to 3000 p.p.m.). The clear supernatant, containing a maximum of 40 p.p.m. suspended solids, was decanted to one-half of the total volume. Two 50 ml. pipetted samples of the concentrated sludge were transferred to 50 ml. centrifuge tubes and centrifuged at 2600 r.p m. for 10 minutes. The clear supernatant liquor was then decanted and the moist solids transferred to a tared gooch by means of a spatula and distilled water washing. For samples containing over 3000 p.p.m. suspended solids the gravity concentration was omitted. A dried solids sample of 250 to 1000 mg. was therefore obtained with a maximum loss of less than 1 per cent due to decantation.

Thirty determinations on different sludges by the two methods gave wide variations in results. It was found that most frequently the small samples gave the highest results. The maximum deviation of the small samples was +37.4 to —20.6 per cent, or a mean deviation of +6.57 per cent. The average deviaiton was +8.96 and —4.87 per cent.

As previously quoted, Standard Methods suggests the difficulty in collection of the original sample. A few results were obtained on a small experimental activated sludge tank. Air was introduced through a porous tube at a rate which appeared to distribute the suspended solids uniformly. Aliquot surface samples were taken for suspended solids before and after additional violent agitation by means of a ladle. Six duplicate determinations with a suspended solids varying from 1500 to 2500 p.p.m. showed that without additional mixing only an average of 75 per cent of the suspended solids would be recorded. Stated differently, the suspended solids without additional mixing were 9.5 to 34.5 per cent or an average of 24.4 per cent lower than the suspended solids of thoroughly mixed liquors. Undoubtedly a similar unequal distribution of suspended solids is present in most large aeration tanks although the variation may not be as great.

Comparison of Volume of Centrifuged Solids and Weight of Solids by Gooch Filter

The volume of centrifuged solids was obtained by centrifuging 15 ml. samples for 10 minutes at 2600 r.p.m. in a graduated 15 ml. centrifuge tube. The sample was transferred to the tube from a 300 to 1000 ml. bottle by means of a large mouth pipette. The graduations were such that the per cent sludge by volume was read directly. The suspended solids were determined by the gooch filter method.

The results of 50 determinations on sludges from one New Jersey activated sludge plan are plotted in Figure 1. The settling characteristics varied from 30 to 90 per cent sludge after one-half hour settling, more or less irrespective of the solids concentration.

Ratios of suspended solids to the volumetric percentage of sludge varied between 500 and 650 irrespective of the concentration of suspended solids. The average ratio was 570, *i.e.,* each per cent of sludge volume was roughly equivalent to 570 p.p.m. suspended solids, or the concentration of dry solids in the wet centrifuged sludge volume was roughly 5.7 per cent.

From Figure 1 much better agreement between the two determinations is achieved if a straight line curve is plotted having the formula $x = 450 + (y - 1)\ 600$ ($x =$ p.p.m suspended solids and $y =$ per cent sludge by volume in a 15 ml. graduated centrifuge tube).

The above formula or curve was used to convert percent volume of sludge to p.p.m. and the results compared to the original gravimetric figures. The maximum percentage deviation of the calculated determination was —11.65 and +15.8 or an algebraic mean of +0.04. The average deviation was +6.06 per cent and —5.14 per cent. In less than 10 per cent of the determination was the deviation greater than ±10 per cent. Maximum deviations do not occur in any one section of the 1000 to 7000 p.p.m. range. Thus in the 1000 to 3500 p.p.m. range the maximum deviation is +10.8 and —9.84 or an average deviation of +5.88 and —4.88 per cent.

In the 3500 to 7000 p.p.m. range the maximum deviation was +15.8 and —11.65 or an average deviation of +10.7 and —6.13 per cent.

Duplicate and triplicate determinations of the per cent sludge by

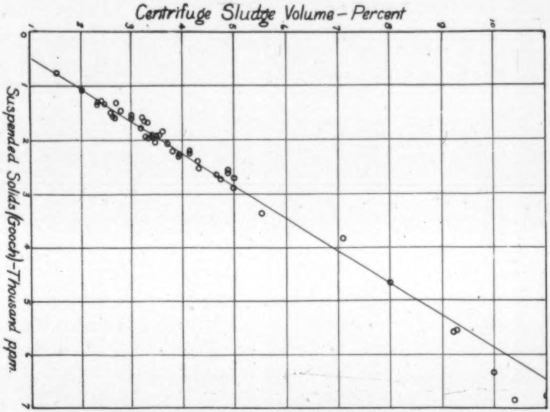

FIG. 1. Correlation of centrifuged sludge and suspended solids (gooch filter). Formula of straight line curve $x = 450\ (y - 1)\ 600$.

volume in 32 activated sludges having a suspended solids concentration in excess of 1000 were made in our laboratory by Hoot.* The greatest variation in check determinations was 20.4 per cent. Only in two determinations did the deviation exceed 7 per cent. The average deviation was 3.79 per cent.

Five activated sludge mixtures were stored for a week at 5° C. and the volumetric percentage of centrifuged sludge determined by the above analyst before and after storage. The results are as follows:

VOLUMETRIC PERCENTAGE OF CENTRIFUGED SOLIDS

Sample	1	2	3	4	5
Unstored	2.7	3.1	3.2	3.3	12.2
Stored	2.5	2.75	3.1	3.1	12.1
Change	−0.2	−0.35	−0.1	−0.2	−0.1
% decrease	7.27	11.7	3.12	6.06	0.82 mean 5.79

Apparently the swelling property of activated sludge is reduced on sludges stored at low temperatures but the increased density of the sludge does not materially effect the accuracy of the suspended solids determination by the centrifuge method.

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* C.W.A. Analyst, N. J. Agricultural Experiment Station, Dept. Water & Sewage Research.

A number of determinations were made on the applicability of the centrifuge method for raw sewage suspended solids. Four 50 ml. samples were centrifuged, the supernatant decanted and the sludge transferred with washing to a 15 ml. graduated centrifuge tube and recentrifuged. The dry solids in the centrifuged sludge volume of five sewages varied from 8.65 to 14.15 or an average of 11.37 per cent. The p.p.m. of suspended solids was calculated from the volume of centrifuged solids by the above average per cent of dry solids and compared with average duplicate gooch filter determinations. The maximum deviation of calculated values was — 19.7 and + 31.2 per cent. The average deviation was + 18.8 per cent and — 16.9 per cent.

The maximum variation of duplicate gooch filter determinations was ± 11.1 per cent or an average of ± 4.39 per cent.

Discussion

1. Extreme care must be taken in the collection of a representative sub-sample from the original sample submitted for analysis.

2. Occasionally considerable error may incur in reading the graduated centrifuge tube. This is particularly so if the speed of the centrifuge is reduced abruptly as the solids at the interface of sludge and supernatant are thrown to one side of the tube and form a banked sludge layer. Proper operation of the centrifuge, however, alleviates most of this error.

3. Consistent reading of the interfacial layer is necessary. The reading should be taken at the bottom of the sludge meniscus. Numerous determinations were made by reading the top of the meniscus. The results gave good correlations with the gooch filter method but the formula $x = 400 + (y - 1)\ 510$ was more applicable than $x = 450 + (y - 1)\ 600$.

4. The readings of sludge volume should be made immediately after centrifuging. The volume of centrifuged sludge increases considerably after ½ hour standing due to imbibition of water.

5. Readings of less than 2 per cent solids by volume are subject to considerable error. It is therefore advisable to double the size of the sample when the suspended solids content of activated sludges is less than 1000 p.p.m.

6. Industrial wastes and infiltration of fine sand and clays will undoubtedly have some effect toward increasing the density of centrifuged activated sludge. If it is assumed that sand and clays in the activated sludges have no material effect on the purification process then the centrifuge method would be a better index of the "active" sludge concentration than the *weight* of suspended solids.

7. The errors of the suspended solids determination by the gooch method are also considerable so that not all of the percentage deviation of the centrifuge method from the gooch filter method can be ascribed to errors of the former method. Under the conditions and results of this investigation the centrifuge method was equally as accurate as the gooch method.

SUMMARY

The volume of sludge after centrifuging for 10 minutes at 2600 r.p.m. was compared to the weight of suspended solids.

Activated sludge samples of variable gravity settling characteristics had suspended solids concentrations of 1000 to 7000 p.p.m. and the resultant moisture content of centrifuged solids was 94 to 95 per cent.

Sewage samples (100 to 400 p.p.m. suspended solids) upon centrifuging produced a sludge containing 86 to 92 or an average of 88.6 per cent moisture.

Applying the formula $x = 450 \times (y - 1)\ 600$ to activated sludges, the calculated weight of suspended solids from the volume of centrifuged solids check within a maximum of + 16 to — 12 or an average of ± 5.5 per cent of the gooch filter method.

Errors in the gooch method are shown to be as great as the deviations of results calculated from the volume of centrifuged solids.

The calculated results of sewage suspended solids from the volume of centrifuged solids deviated from the gooch filter method by ± 20 to 30 or an average of ± 17.5 per cent, whereas duplicate gooch filter determinations deviated from the mean by an average of ± 4.39 or a maximum of ± 11.1 per cent.

CONCLUSION

The determination of suspended solids by the volume of centrifuged solids of activated sludge liquors affords a rapid and easy method which is of sufficient accuracy for plant control purposes.

REFERENCES

1. T. Haseltine, THIS JOURNAL, **4,** 465 (May, 1932).
2. W. Donaldson, THIS JOURNAL, **4,** 56 (Jan., 1932).
3. E. Theriault, U. S. Public Health Service, *Bull.* **132,** p. 24 (19).
4. S. Vermilye, *Proc.*, 19th N. J. Sew. Works Assoc., p. 44 (1934).
5. R. Voelker, THIS JOURNAL, **5,** 947 (Nov., 1933).

ACTIVATED SLUDGE TREATMENT WITH EXTREMELY LOW SOLIDS *

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Considerable data are available from various sources showing the effect of different amounts of suspended activated solids on purification in the treatment of sewage by the activated sludge process. This information has been presented from both laboratory experiments and from plant scale operation records. The results of plant scale experiences have been reported with activated solids as low as 1200 to 1300 p.p.m. (1) (2). The effect of the continuous use of lower amounts of solids on purification have been confined to laboratory experiment reports.

Within the last three years the writer has had an opportunity to study plant scale operation with solids in amounts as low as 150 p.p.m. It is thought to be of theoretical interest to report some of the observations of this study from the standpoint of (1) the minimum amounts of solids which can be maintained under continuous plant operation in a so-called "active" condition, (2) the relative "unit efficiency" of purification of these low solids and (3) the settling characteristics of the sludge floc formed.

Conditions of Operation

These data were compiled from operating records of a 1,200,000 gallons per day activated sludge plant, serving one of the New Jersey State Hospitals, during a stage in the development of the plant when operating conditions made it necessary to carry extremely low amounts of solids in the aerators. These conditions existed for a period of approximately a year and six months. The period of operation for each of the ranges of solids noted in the following graphs varied from four to seven months. During this time the plant was maintained in continuous operation and the solids held in the tanks in the amounts noted by continuous waste of excess sludge.

A composite analysis of the sewage treated during this period is as follows:

Calculations used in the following discussion have been based upon the analysis of the primary settling tank effluent given above. This effluent after mixture with 40 per cent return sludge entered the aerators

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* Journal Series Paper, N. J. Agricultural Experiment Station, New Brunswick, N. J., Dept. Water and Sewage Research.

	Raw Sewage	Primary Settling Tank Effluent
pH	7.8	6.9
B.O.D., p.p.m.	235	185
Suspended Solids, p.p.m.	156	74
Settleable Solids, Cc. per Liter	4.0	0.3
Total Solids, p.p.m.	580	456
Ether Soluble Material, p.p.m.	43.3	–
Diss. Ox., p.p.m.	1.0	0.0
Total Acidity, p.p.m.	0.5	13.0
Total Alkalinity, p.p.m.	130	100
Chlorides, p.p.m.	21.0	21.0

directly. The 40 per cent volume of return sludge was maintained more or less constant throughout all periods.

The maximum detention period in the aerators during the period under observation was 5 hours on a 16-hour day rate of flow.

Dissolved oxygen was maintained at all times above 0.5 p.p.m. in the influent end of the aerators. At the outlet end dissolved oxygen varied between 1.2 and 3.0 p.p.m. depending on the quantity of solids in the aerators.

Discussion of Results

Loss of "Activation."—The interpretation of the point where loss of "activation" occurs must necessarily depend on the definition of that term. At the present time the term "activation" is used in a broad sense and lacks the common agreement of investigators in the sewage field as to its specific meaning. In various definitions and descriptions in the literature (3, 4, 5) its identification is tied up with appearance, biological and chemical composition, physical structure, flocculating and adsorbing ability, clarification of the sewage liquor and ability to transform the chemical and biological characteristics of the sewage. Moreover there is a lack of agreement on definite values which can be contributed to these characteristics for an evaluation of "active" sludge.

The term activation is used in this paper in the sense which appears to be most generally employed by sewage plant operators, namely, that quality of the aerated suspended solids which enable it to (1) flocculate and adsorb suspended materials and (2) purify the sewage liquor by the combined action of flocculation and oxidation.

An observation as to the point where loss of activation might occur is thought to be of interest because it is a current belief to some extent by activated sludge plant operators that one of the major dangers of maintaining low quantities of activated solids in the aerators is the possibility of the solids losing their state of "activation." The thought is that the loss of "activation" occurs by reason of either a temporarily high raw sewage load on the aerators due to sewage flow fluctuations or similarly by the effect of a continuous load of raw sewage on the activated sludge floc in excess to the normal load the floc is supposed to carry. It is logical to assume that there is such a point of overload where sufficient deterioration of the floc will occur to cause it to lose the general characteristics of "activated" sludge. Experiences at this plant with low amounts of solids show, however, that at least for the local sewage the point where loss of "activation" occurs is extremely low. Those experiences are correlated in Figures 1 and 2 which show the purification characteristics with respect to B.O.D. and suspended solids removal with aerator solids varying between 150 and 2290 p.p.m.

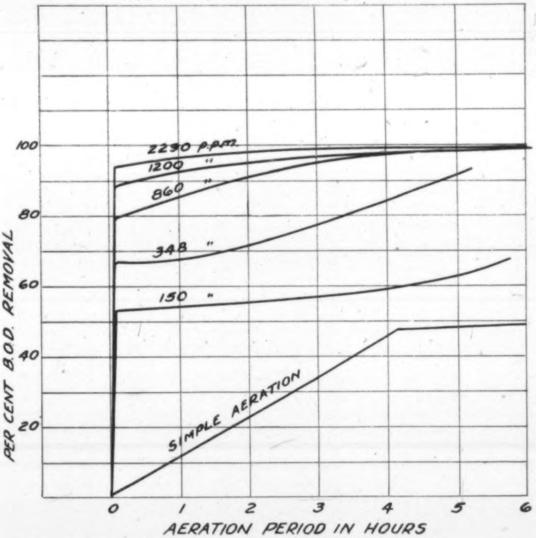

FIG. 1. Progressive reduction in B.O.D. (5-day) through aeration tanks.

It appears from the nature of these curves that "active" floc characteristics were maintained in amounts as low as 150 p.p.m. under actual operating conditions for a period of at least four months. While the degree of purification increased with increasing amounts of solids the general characteristic of activated sludge for immediate clarification and B.O.D. reduction was maintained with the lowest solids used. This is exemplified in the same figures by comparison with simple aeration

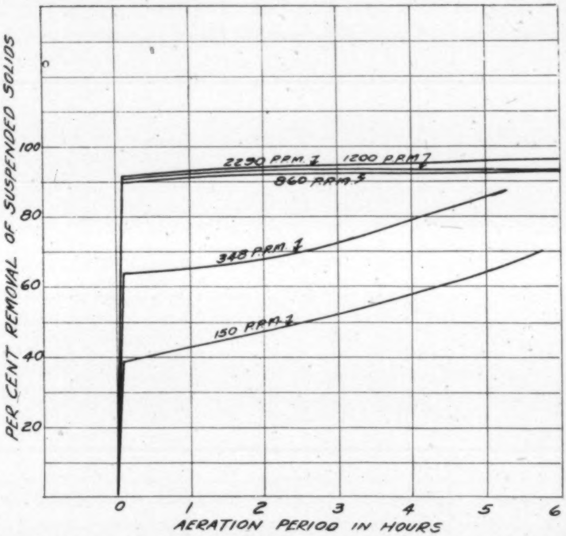

FIG. 2. Progressive reduction in suspended solids through aeration tanks.

under the same conditions with the exception that no return sludge was used.

Relative "Unit" Efficiency of the Floc.—The active condition of the sludge floc in the low amounts seems to be confirmed still further by the relative "unit efficiency" in B.O.D. and suspended solids removal. If the returned suspended solids were reduced materially in their state of "activation" the effect on purification should be, first, a reduced "unit" ability to adsorb and entrap suspended materials in the applied sewage upon initial contact, and second, a reduced "unit" ability for the slower second stage purification by removal and oxidation of the more colloidal and soluble organic materials.

Calculations on this basis show to the contrary that the relative "unit" efficiency of the lower solids upon initial contact is the greater. Study of Figures 1 and 2 show that whereas 860 p.p.m. of activated solids removed 0.18 p.p.m. B.O.D. per unity upon initial contact (5 minutes), 150 p.p.m. solids removed 0.71 p.p.m. of B.O.D. in the same length of time. Correspondingly, the "unit" removal of suspended solids for 150 p.p.m. of activated sludge was 0.18 p.p.m. whereas for

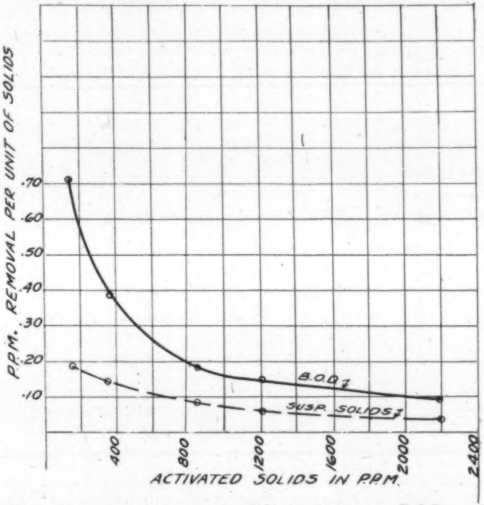

FIG. 3. Effect of varying amounts of solids on first stage B.O.D. and suspended solids removal.

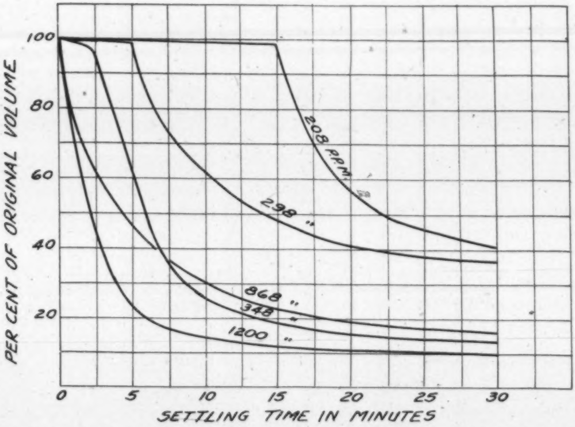

FIG. 4. Settling characteristics of activated sludge floc in low quantities.

860 p.p.m. of activated sludge the removal was 0.08 p.p.m. per unit. Intermediate values for both suspended solids and B.O.D. reduction are given in Figure 3.

Similarly an inspection of the second portion of the curves demonstrates that the "unit" removal of B.O.D. and the suspended solids is likewise maintained as great or greater with the low solids as with the high solids.

Another interesting aspect shown by purification with low amounts of solids is the nature of the second stage of purification. While the major trend is in the same direction for all amounts of solids there appears to be a minimum amount of solids below which the purification curve takes a different form. With the higher quantities of solids the rate of purification after the first stage decreased with increasing aeration time, while with the lower amounts of solids the purification rate increased with corresponding time increase. The point of change lay between 348 and 860 p.p.m. solids.

Settling Characteristics.—The settling characteristics of the activated sludge formed with low solids demonstrates some characteristic features. As in the reduction in B.O.D. and clarification of the sewage liquor, the settling characteristics shows two stages in the settling process. This twofold nature of settling became increasingly noticeable with decreasing amounts of activated solids. The first stage appeared to be one of flocculation. The second stage followed the normal course of settling. With the lowest solids the initial flocculation was quite prolonged, and less complete than with higher concentration. The density of the settled sludge floc was also considerably less. During the settling process, the line of demarcation between the supernatant liquid and the upper sludge level was always distinct, but straggling flocculation continued in the supernatant liquor during the major part of the settling period. The practical effect of this "delayed flocculation" was apparent under operating conditions in increased solids in the plant effluent.

The reason for this delayed flocculation with lower solids would seem to be due to insufficient quantities of sludge floc particles in the liquid to allow close enough contact for immediate flocculation. Such being the case, the dividing line for sufficiently close contact of particles for quick flocculation in this instance lay between 348 and 868 p.p.m., the same value where the change in characteristic of the second stage purification occurred.

SUMMARY

Observations were made on plant scale operation with the use of small quantities of activated solids. The study was confined principally to a range of suspended solids between 150 and 868 p.p.m. These results show that under the conditions of this study:

1. The "activation" of sludge was maintained under continuous plant operation with normal detention period using solids in amounts as low as 150 p.p.m.

2. While the overall purification efficiency was less, the relative "unit" of efficiency of the lower solids with respect to first stage B.O.D. removal and clarification was maintained.

3. Similarly in the second stage purification the relative "unit" efficiency of the low solids were as high or higher than the higher solids.

4. The settling of activated sludge developed under low quantities of solids in the aeration tanks shows two distinct stages; First, flocculation of the suspended particles and second, normal settling. The length of time required for the initial flocculation stage increases with decreasing amounts of solids.

REFERENCES

1. G. M. Ridenour and I. O. Lacy: "Activated Sludge Plant with Brush Aeration." THIS JOURNAL, **4**, 263–274 (1933).
2. G. M. Ridenour: "Observations on Bulking in a Surface Aeration Activated Sludge Plant." THIS JOURNAL, **5**, 75–82 (1933).
3. F. W. Harris: Glasgow Report, p. 4 (1923).
4. W. R. Copeland: "Activated Sludge Defined." *Eng. News-Rec.*, **73** (1916) and **80** (1918).
5. A. M. Buswell: "Bicrobiology and Theory of Activated Sludge." *Jr. Am. Water Works Assoc.*, **10**, 309 (1923) and *Eng. News-Rec.*, **91**, 259 (1923).

THE BIOCHEMICAL OXYGEN DEMAND TEST, AS INFLUENCED BY THE RATIO OF ORGANIC CARBON TO TOTAL NITROGEN *

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It is a generally recognized fact that bacteria responsible for the biochemical oxidation of organic materials require not only carbonaceous matter to supply enegry but also nitrogen, potash, and phosphorus with which to build cell substance and to permit reproduction. Butterfield, Purdy and Theriault[1] hold that biochemical oxidation is a function of the rate of growth and reproduction of the bacteria involved, rather than the actual numbers present at any one time. If this be true, then the maximum B.O.D. of a waste can be obtained only when sufficient cell building elements are present to insure that the food or energy supply may be the limiting growth factor.

While a certain amount of work has been done in the past on the relative quantities of these cell-building elements necessary in the B.O.D. test, a survey of recent literature failed to reveal any very definite statements as to just what their desirable concentrations might be. The studies here reported were undertaken to shed some light on this matter.

General Procedure

Nitrogen being required by living matter in greater quantities than either potash or phosphorus and, further, being the one of these three elements probably most likely to be deficient in sewage and various trade wastes, it was decided at the outset to limit the scope of these studies to a consideration only of the carbon-nitrogen ratio.

Accordingly, B.O.D. determinations were made on solutions of lactose and maltose, materials devoid of nitrogen; and upon mixtures of sterile lactose and sterile domestic sewage. For each series of determinations the proportions of lactose and sewage were varied so as to vary the carbon-nitrogen ratios. Seeding was in all cases uniform within each series and was of a degree demonstrated to be ample by a concurrent but as yet unfinished study of the quantity of seeding necessary in the B.O.D. test.

Laboratory Procedures

In all of this work dissolved oxygen was determined by the Winkler Method as modified by Theriault and McNamee,[2] for use with samples containing large amounts of organic matter. N/40 sodium thiosulphate was standardized before each run.

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* Presented at the Seventh Annual Convention of the Central States Sewage Works Association, Fond du Lac, Wisconsin, Sept. 27, 1934.

Dilutions were prepared by siphoning approximately two-thirds of the required amount of dilution water into a clean one-liter cylinder and then adding the appropriate amounts of sterile sewage and sterile lactose solution, after which the remainder of the dilution water was added. Thorough mixing was accomplished with a perforated metal plunger. The contents of the cylinder after mixing were siphoned into 260 ml. ground-glass stoppered bottles provided with water seals. The samples were incubated at 20° C. ± 1°.

For each dilution containing both sugar and sewage a blank was prepared containing only the amount of sewage used. The B.O.D. results were calculated for the lactose only by subtracting the oxygen demand of the sewage blank from the combined demand.

The sugar solutions were carefully made up, using an analytical balance and a volumetric flask, to contain exactly one gram of sugar per liter. The solutions were then sterilized by autoclaving at fifteen pounds pressure for one-half hour.

The sewage used was obtained from the effluent channel of the primary tanks at the Burke Sewage Disposal Plant, Madison. The sewage was diluted with an equal volume of distilled water and autoclaved under the same conditions as were the sugar solutions. The organic nitrogen content of 14.2 p.p.m. was determined by the usual Kjeldahl method, using copper sulphate in the digestion. No nitrate or nitrite nitrogen was present. The organic carbon content of the sewage was found to be 41.4 p.p.m. and was obtained by evaporating 700 ml. of the sterilized sewage on a water bath and running combustions by the Pregl Semi-Micro Method upon representative samples of the dried solids. The ash left in the boat after the combustion was moistened with a saturated solution of ammonium carbonate, and placed in a drying oven to drive off the excess ammonium salt. The converted ash was then ignited, the carbon dioxide evolved being weighed and its amount subtracted from the amount evolved in the first combustion. The net result was used in calculating the organic carbon content of the sewage. The reason for carrying out this additional procedure with the ash is that in the first combustion the carbon dioxide produced comes from inorganic carbonates as well as from the oxidation of organic carbon. By reconverting the oxides of the ash to carbonates and determining the amount of carbon dioxide evolved from them it is possible to correct for inorganic carbon originally present.

Aged distilled water containing 300 p.p.m. of sodium bicarbonate was used for dilution purposes. The pH of this water was ordinarily 7.3. The seeding for all except the first two series consisted of 20 ml. per liter of raw Lake Mendota water and 1.5 ml. per liter of the filtrate resulting from four successive filtrations of settled domestic sewage through coarse filter paper. Incubation for five days at 20° C. ± 1° of dilution water prepared in this manner resulted in an average loss of dissolved oxygen of 0.20 p.p.m.

Bacterial counts were made on plain nutrient agar,[3] the plates being incubated for 48 hours at 20° C ± 1° before the counts were made. The number of organisms in the seeded dilution waters ranged from 1,500 to 2,500 per ml.

RESULTS

The first series of runs was made with 0.1 per cent solutions of lactose and maltose with no sewage or other source of nitrogen added. Seeding was accomplished by adding increasing amounts of a suspension of sewage bacteria prepared by washing colonies off agar plates with sterile water. The degree of seeding ranged from 3,200 to 360,000 bacteria per milliliter. Five-day incubation of the dilutions so prepared failed to result in appreciable dissolved oxygen losses. The addition of three drops of nutrient broth[3] to a few of these dilutions caused them to be completely deoxygenated when incubated an additional five days, while a blank containing a like amount of broth lost only 2.0 p.p.m. of oxygen.

Four independent series of dilutions, in which the amounts of lactose and sewage used were varied to give carbon-nitrogen ratios ranging from 5.7 to 287, were prepared and incubated for five days. The B.O.D. results from these series are summarized in Table I and are shown graphically in Figures 1 and 2.

TABLE I.—*Observed 5-Day Biochemical Oxygen Demand of 0.1 Per Cent Lactose Solution with Various Amounts of Sterile Domestic Sewage*

B.O.D. in p.p.m.

ml. Sterile Sewage	ml. Lactose Solution	Organic Carbon	5 day B.O.D.				
		Total Nitrogen	Series 1	Series 2	Series 3	Series 4	Average
1	10	287/1	193	122	169	191	169
2	10	145/1	204	148	177	207	184
3	5	46.6/1	384	347	357	372	365
4	5	37.8/1	363	351	363	357	359
5	2.5	16.9/1	448	420	474	450	448
6	2.5	14.6/1	450	406	465	448	442
7	2	10.9/1	450	435	480	458	456
8	2	9.9/1	454	440	483	450	457
9	1	6/1	549	504	534	510	524
10	1	5.7/1	579	540	495	534	537

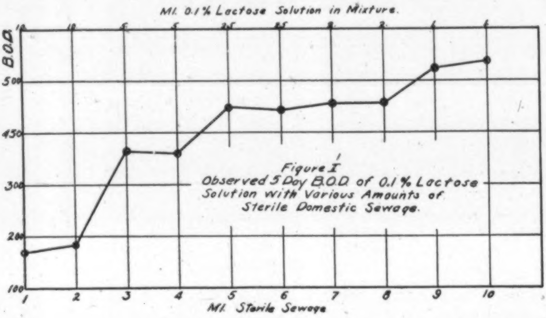
Figure I
Observed 5 Day B.O.D. of 0.1 % Lactose Solution with Various Amounts of Sterile Domestic Sewage.

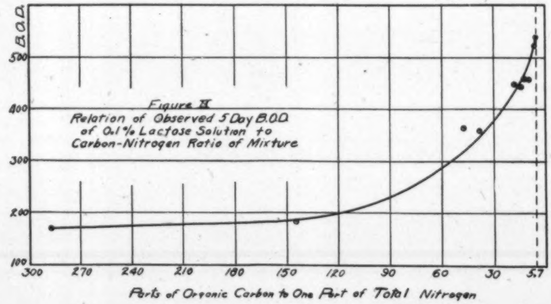
Figure II
Relation of Observed 5 Day B.O.D. of 0.1 % Lactose Solution to Carbon-Nitrogen Ratio of Mixture

It was necessary to vary the quantities of sugar solutions used in these series in order to cover the wide range in B.O.D. Considering Figure 1 it will be seen that each large percentage decrease in the amount of lactose is accompanied by a sharp increase in the observed B.O.D. The decreases in the lactose were generally 50 per cent and, when of that magnitude, made sharp decreases in the amount of carbon in the system. On the other hand the sewage, and consequently the nitrogen, was increased relatively slowly. It is noted that in all cases the increase in the B.O.D. observed after an increase in sewage only is much less than observed after a decrease in the lactose.

In Figure 2 the data from these series are shown with the B.O.D. plotted against the ratio of organic carbon to total nitrogen as it actually was determined in the individual dilutions. It is here indicated that a change in the carbon-nitrogen ratio alone of from 287 down to

5.7 resulted in raising the apparent B.O.D. of the lactose solution more than three-fold, from an average of 169 p.p.m. to an average of 537 p.p.m. It is further indicated that relatively little change in the B.O.D. results are to be expected with the carbon-nitrogen ratios above approximately 120 whereas below this value the change is marked, becoming increasingly rapid as the extreme low values are approached.

Table II and Figure 3 show the results of another series, one designed to set forth more clearly the difference between the oxidation rates with carbon-nitrogen ratios at the highest and lowest values attained in the previous runs. In this series the oxygen depletions and the numbers of bacteria present in each dilution were observed daily for five days.

Table II.—*Comparison of Rates of Biochemical Oxidation of 0.1 Per Cent Lactose Solution at High and Low Carbon-Nitrogen Ratios*

Results in p.p.m.

Organic Carbon	B.O.D.				
Total Nitrogen	1 day	2 days	3 days	4 days	5 days
6/1	150	300	390	405	510
287/1	3	7.5	12	40.5	96

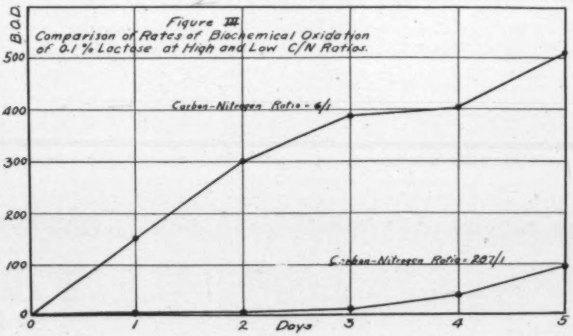
Figure III
Comparison of Rates of Biochemical Oxidation of 0.1 % Lactose at High and Low C/N Ratios.

The curve shown for the carbon-nitrogen value of 6.0 closely approximates the curve which would be obtained if Phelps' formula were applied using 510 p.p.m. as the 5-day point, and may therefore be considered to represent nearly if not quite normal oxidation. Only 12 p.p.m. oxygen demand was observed at the end of three days with the higher ratio, and less than 100 parts of oxygen were used in five days. This curve is noted to be concave rather than convex and is not at all typical for oxidation curves.

In the dilution with a carbon-nitrogen ratio of 6.0 a maximum bacterial density of 5,600,000 per ml. was reached on the second day, after which the population fell to around 1,700,000 per ml. In the nitrogen deficient dilution there were noted only 490,000 bacteria per ml. on the second day. By the fourth day the numbers had increased to 560,000 per ml. No count was obtained on the fifth day, therefore the maximum density is unknown.

Discussion

It is assumed that the effects noted in this study were brought about largely by varying the relative proportion of nitrogen in the various series. This assumption is borne out in part by Allgeier, Peterson and Juday.[4] Working on the availability of carbon in certain aquatic materials under aerobic conditions of fermentation, they found that, on being fermented, residues from the evaporation of lake water having carbon-nitrogen values of from 16.6 to 25.4 gave up only 18–42 per cent of their carbon as carbon dioxide in 31 days, while certain algae, plankton and white clover having carbon-nitrogen values ranging from 4.1 to 14.6 gave up 61–67 per cent of their carbon in a like period. It is fully realized, however, that the sewage used as a source of nitrogen contained also potash and phosphorus, and the possibility of these latter being responsible in part is admitted. Further work along this line should be undertaken, using pure compounds as sources of nitrogen and controlling the potash and phosphorus.

It would appear that the fundamental effect of a deficiency of nitrogen in the B.O.D. test is to limit the rate at which the bacteria concerned can grow and multiply. If this is actually the case, we would expect that two systems containing the same amount of energy material, one with plenty of nitrogen and the other deficient therein, would have the same ultimate demand. Eldridge[5] added increasing amounts of raw sewage to lactose solutions and incubated them for periods up to twenty days. He found that though the short-time demands varied considerably, the samples having the most sewage being the highest, the twenty-day demands of all samples were nearly identical.

Summary

The results obtained in the experimental work herein discussed indicate that—

(1) The rate of biochemical oxidation of an organic waste is strongly

influenced by the ratio of the organic carbon to the total nitrogen contained therein, though the ultimate demand is probably not affected.

(2) The rate of oxidation is very low with a carbon-nitrogen ratio of 120/1 and tends to decrease slowly at higher ratios.

(3) The rate of biochemical oxidation increases rapidly at ratios below 120/1 and the ratio conducive to maximum 5-day oxygen demands is probably in the neighborhood of 5.7/1.

REFERENCES

1. C. T. Butterfield, W. C. Purdy and E. J. Theriault, "Experimental Studies of Natural Purification in Polluted Waters." *Public Health Reports,* Vol. **46,** No. 8, February 20, 1931, pp. 393–426.
2. E. J. Theriault and P. D. McNamee, "Dissolved Oxygen in Presence of Organic Matter, Hypochlorites, and Sulfite Wastes." *Jour. Indus. and Eng. Chemistry,* Anal. Ed., **4,** 59 (1932).
3. *Standard Methods of Water Analysis,* American Public Health Association (1933).
4. R. J. Allgeier, W. H. Peterson and C. Juday. *Internationale Revue der gesamten Hydrobiolgie und Hydrographie,* **30,** 371–378 (1934).
5. E. F. Eldridge, "More About the Biochemical Oxygen Demand Determination." *Sewage Works Journal,* **5,** 5 (1933).

Plant Operation

THE COMBINED COLLECTION AND DISPOSAL OF SEWAGE AND FOOD WASTES *

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Even in the short number of years by which sewage treatment science measures time, the brief interest shown in the queston of combined disposal of sewage and garbage has been too fleeting to produce the understanding, mellow viewpoint which sanitarians have acquired toward other phases of municipal practice. The topic is one which, of necessity, is concerned with the two major municipal waste collection and disposal problems and inevitably interwoven with home hygiene procedure.

Introductory

The subject of combined disposal of sewage and garbage requires a complete re-orientation of ideas on the part of the sanitary engineer as well as the layman. We have thought too long that sewage and garbage are two entirely different wastes for us to pass too lightly over the problem of changing our concepts. The process of changing basic belief cannot be carried out by a wave of the hand; it must come from scientists as a result of reasonable proof.

Only a decade ago, investigators at Lebanon, Pa., first ground municipal garbage and discharged the resulting pulp into the sanitary sewer for treatment in Imhoff tanks. No confirmatory data of scientific value were added to this novel experiment for many years. Recently studies of Prof. Fair at Harvard University and studies at Baltimore, Maryland, have brought further information to light and scientific interest has been awakened. Recently, information published by Prof. Hyde of the University of California and by Prof. Babbitt of the University of Illinois has created further interest in the amenability of treating garbage with sewage.

Even these evidences of the ability of sewage treatment works to serve in the dual capacity of destroyer of the power for evil of both sewage and garbage have not caused widespread interest in the possibilities of revolutionizing municipal sanitation practice. The complete divorcement of the garbage pail and the sanitary sewer house connection has established a precedent difficult to overcome.

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THE SIMILARITY OF SEWAGE AND WASTE FOOD

If pressed to supply a general truth, I would say that the edibles which enter a home leave it. The portion of the food consumed and portions of unconsumed food find their way into the house sewer as normal constituents of sewage and then enter the complex sewerage and sewage treatment system. The portion of food discarded either in the preparation of meals or as rejects therefrom enters the garbage pail and finds its way into the equally complex system of municipal collection and disposal.

Municipal sewage of today is a motley mixture of water-carried wastes. What started out to be merely the use of waste water to carry dangerous human excreta from the home has developed, by the natural growth of home life and home services, into a stream of sewage which carries everything but the kitchen sink. In discussing the changes which time has wrought in the quality of sewage, in an article entitled "Sewage a la Mode" published last year in Sewage Works Journal, the writer stated that "sewage reflects the big changes in urban living as well as the trivial. The glorious rise in the standards of living, the sweeping revamping of the industrial world, the restrictions of a constitutional amendment, the pinch of depression—all are reflected as exactly as is the never-say-die spirit of the tomato seed."

Perhaps the most dangerous constituents of domestic sewage are the highly organic body wastes and the equally putrefactive kitchen wastes. The other wastes such as wash water, laundry water and the like, are in themselves not seriously objectionable to sight, smell or health. It is important to the present discussion that both body wastes and kitchen wastes are closely related to the wastes which enter the garbage pail. When viewed in this light, *sewage* is the wastes which the *human body* discards and *garbage* is the wastes which the *human* discards. The wastes of body metabolism are, of necessity, basically like the wastes which are discarded before digestive processes come into play. Since sewage contains many food particles which are discarded in the process of food preparation or which the human refuses to consume, the terms *sewage* and *garbage* are so scientifically indeterminate as to be misleading.

The relationship between sewage and garbage is more distinct than is usually conceived. I eat certain portions of food which you reject as garbage. You consider as tid-bits certain parts which I cannot eat. The nursery rhyme about Jack Sprat who ate no fat and his wife who ate no lean illustrates the point clearly. In the preparation of food, some portions are wasted down the kitchen sink strainer because of small size, other remnants are thrown into the garbage pail—and the rest is served, either to become sewage or to be left on the plate to be scraped into the garbage can or washed down the sink drain.

Sewage is the *liquid waste* of the community and garbage is the *solid waste*. Yet, both are mixtures of liquid and solids. Sewage contains 99.9 per cent water and garbage contains 80 per cent water. The solids-content of both are highly organic, subject to bacterial decomposition, productive of odors, the breeding ground for insects and dangerous to health.

It is small wonder, then, that the proposal of grinding garbage and discharging it into sewers for treatment with sewage has scientific merit. Past studies have already indicated that pulped garbage solids and sewage are amenable.

In the 1923 experiments of Fox and Davis at Lebanon, Pa., two tons of garbage were ground daily and discharged into one of the six Imhoff tanks at the sewage works. This application of one-sixth of the city's garbage production into one-sixth of the plant's tank capacity for the period of nine months led the investigators to conclude that the amount of measurable sludge in the tank was increased less than one-tenth of one per cent, that the drying period or fertilizer quality of the sludge was not impaired and that tank foaming was reduced. In the light of increased load of solids it is difficult to understand how the sludge deposit in the Imhoff tank was increased so negligibly.

The similarity of sewage and garbage lends credence to the Baltimore studies of the ability of pulped garbage and sewage to digest into a satisfactory end-product. As a result of painstaking laboratory tests, it was shown by Keefer and Kratz that mixtures of equal quantities of garbage and sewage, on the basis of volatile solids, digest rapidly when seeded with sludge. Daily additions of five per cent of the initial volatile solids of sewage-garbage gave satisfactory digestion and the production of 750 to 800 cc. of total gas and 500 cc. of methane gas per gram of dry volatile solids added. An inoffensive sludge of satisfactory drying ability was produced. The investigators suggested that daily additions of more than 5 per cent of sewage-garbage to digesting sludge might prevent satisfactory digestion.

RESULTS OF SCHENECTADY STUDIES

The writer's interest was aroused in the question of combined disposal of sewage and garbage as a result of local conditions. The Schenectady Imhoff tank-trickling filter sewage works, placed in operation in 1915, is capable of treating but 60 per cent of the city's total sewage flow. The shallow tanks have been seriously overloaded and budget costs, while as low as any installation doing similar service, reflect the manual labor required to maintain satisfactory operation. The general decadence of the works has long indicated that inexorable old age was creeping on. The plant is giving 60 per cent of the sewage unnecessary refinement of treatment, while 40 per cent of the sewage pours untreated into the river, at unintercepted points.

At the same time, the Schenectady garbage reduction process was shut down because of the serious sag in the fertilizer and grease market and the rapid decay of the mechanical units.

Coincident with these conditions, the Federal government's offer of PWA funds appealed to the spirit of those commmunities which sought to get something for nothing—and put men to work doing it. It fell to the lot of the writer to father the design of both a modernized separate sludge digestion plant and an incinerator for the city. What more natural course could be open than to combine the two problems, install added digestion facilities at the new sewage works, convert the reduction plant, which lies adjacent to the trunk sewer, into a municipal grinding station and make combined sewage-garbage treatment a reality?

It is a matter of history that the suggestion for combined disposal fell upon the deaf and disbelieving ears of the city officials. The seriousness of the Schenectady rubbish dump situation made the construction of a garbage-rubbish incinerator popular. An incinerator was designed and the dual disposal idea did not materialize. It is proof of the weight of precedent, that the dual disposal idea, in so likely a situation, was looked upon as an untried novelty, even by officials, who continually confuse the sewage plant and the garbage plant in conversation and who view both installations mentally as places to avoid.

One good turn deserves another—and one good idea deserves another. If the municipal collection of garbage for grinding and discharge into the sewer is a good idea, why would it not be better to handle the process of sewage disposal at the source? Do we collect sewage in buckets, transport it through the city streets in trucks to a central station and then dump it into the sewer? Why, then, do we propose to do just that for garbage? The sewer connection in the home can serve as the outlet for food wastes as well as for sewage. Why not dispose of the two materials as one?

There are two aspects of the home disposal proposal. One concerns the householder and the other the municipal sanitation policies of the community. For the householder, the instantaneous disposal of waste food at the home, as produced, would be an improvement in home hygiene closely second to that afforded by the water-carriage method of sewage removal.

By the broader concepts of what constitutes health hazards, it is not difficult to class the present practices of waste food handling in the home as seriously insanitary. The accumulation of decomposable wastes in the kitchen sink or the "sanitary" kitchen can, the rehandling of these wastes by the housewife, the trip to the outdoor garbage can in all weather or the transportation of smelly containers down befouled dumbwaiters in apartment houses, the garbage can with its odors, flies, maggots and slops remnants after emptying, all seem out-of-date in the modern home, in the unfenced backyard and to the fastidious housewife.

Home disposal of waste food, as produced, would eliminate the garbage can and its attendant ills. Wastes would be discharged fresh rather than in the decayed, acrid, garbagy condition resulting even from the most frequent collection schedules possible in the average community. Collection costs would be eliminated. While rubbish and ashes would require collection, less frequent collections of these non-putrescible wastes would suffice.

Every sewage works operator has been impressed with the large amounts of garbage which enter his plant. There is every evidence that sewers are now being used for the rapid disposal of food remnants, as well as for the most surprising array of modern-day cast-offs. Is this practice one of convenience or is it practiced to save the expense and labor of having garbage removed from the home by collection systems?

Schenectady renders a normally frequent collection service, by city forces so that no direct charge is made to the householder. In addition, Schenectadians are spared the inconvenience of having to carry full garbage cans to the curb and bring back the empty containers after the collection vehicle has made its visit. Schenectady supplies the unusual service of cellar and backyard collections and returns the containers to their accustomed places.

In spite of all this service, Schenectady's sewage gives irrefutable proof of the prevalent custom among housewives of using the toilet as their garbage pail. During one day's observations of the trash captured by the bar rack during March, the following garbage particles were hand-separated from the capturings: pieces cooked turnip, pieces sphagetti, canned peas, cooked carrots, celery stalks, half lemon, pieces butter beans, chicken gizzards, orange peels, pieces parsnip, potato peelings, pickling spices, lettuce leaves, half dill pickle, tea bags, piece apricot, whole tangerine peel, piece fat meat, banana skin, chunk pork rind, corn kernels, dandelion greens, pecan nut meat, peanut shells, fish roe, four gold-fish, cooked mushrooms, bologna rind, cooked onions, apple core, whole beet, slice pineapple, half fried egg, olives, lamb fat, piece bread, half pimento, half frankfurter.

During mid-summer, the presence of seasonal fruits and vegetables was noted in the sewage. In addition to the usual staples mentioned in the above list, the following other items were hand-picked from the trash: hundreds of fresh peas, watermelon rind, cucumber peelings, slices lemon, many grapes, cherries, raw carrots, numerous string beans, much tomato remnants, Italian beans, radishes, strawberries, thimbleberries, red peppers, cantaloupe pulp and seeds, asparagus, pea pods, milk bottle caps from five dairies, a whole grove of lettuce leaves, cabbage leaves, kidney beans, enough spinach to tame the entire youth population, blueberries, rhubarb, stalks of broccoli, etc., etc.

I do not know how many items of food are consumed by Schenectadians but these 70-odd items prove that the housewife does something with them besides make the tedious trip to the garbage can. In one day's collection of 783 pounds of bar screenings, the writer's laborers picked 45 pounds, or about 6 per cent, of true garbage. Only easily recognizable and separable material was sorted.

The solids so picked were all too large to pass through the sink strainer in the kitchen. It is evident that much finely comminuted food solids are washed down the drain in preparing food and washing dishes and that these solids become "normal" constituents of sewage. This was proved by placing a 1/4-in. hardware cloth screen in front of the bar rack for short periods once every hour of the day. It was found that the screen captured many fine solids which contained from 20 per cent of garbage at 10 A.M. to 2 per cent at 9 P.M., as judged by eye. The early morning hours produced no fine garbage solids. It was further found that the skimmings from the Imhoff tanks were of food nature, in major extent.

Feasibility of Home Disposal of Waste Food

If the finer food solids are recognized as normal, unavoidable constituents of sewage and the large solids entering through toilets are illegitimate additions to the flow, and if the food wastes are similar in nature to normal sewage solids of true physiological waste nature, it would appear that the only difference between garbage and sewage solids of domestic nature is one of size. If a grinder can be depended upon to comminute waste food solids, the passage of such food through the unit would produce normal sewage constituents. I do not expect you to agree, at once, with this conclusion, but the contention seems to be true in the light of present-day sewage character and present-day home habits.

If universal home disposal of waste food into sewers became a reality there would be many serious sanitary questions involved.

Would a simple home disposal unit be practical?
Would the house plumbing pass the wastes?
Would the sanitary sewers carry the new-type sewage-food mixture?
Would the treatment works properly treat the new type sewage?
What increased capacity would be required at plants?

The writer has used a home grinder for several months and has discharged all waste food from his home into the sanitary sewer, with the permission of the City. After months of use, the house drain was free from deposition. Examination of the soil pipe by light indicated the same condition. The sewer at the first manhole below the lateral showed no signs of deposition.

Experiments carried out at the treatment works by synthetically regulating the velocity of flow in a reversing channel to rates of about one foot per second, indicated that the ground solids admitted to the flow were easily carried by the sewage without settling. The light, fluffy, pulpy nature of the food wastes resulted in similar reactions in the laboratory. It is evident that macerated food solids should be conducted along sewers by even poor sewage velocities.

The freshness of the material resulted in no odors other than the characteristic odor of the food itself. The grinding of stale garbage resulted in acrid odors. The freshness and firmness of the food remnants picked from the bar rack indicate that home-ground wastes would reach treatment works in non-septic conditions and that no unusual sewage odors would result.

Tests carried out by the writer prove that the food solids, when mixed with sewage in the expected concentrations, settle readily and leave a clear effluent. Imhoff cone tests actually indicated the ability of sewage-food mixtures to settle more efficiently than sewage alone and to produce an effluent of less turbidity, despite the addition of some colored liquor with the pulped food. This phenomenon is evidently caused by the mechanical floculation action caused by the pulpy, voluminous character of the food solids. The addition of paper pulp for the production of similar floculation action is today being recommended. The ability of turbid waters to settle more rapidly than clearer waters is generally recognized.

Extensive tests carried out by the writer prove that the mixture of sewage and food solids, which would be deposited by sedimentation, would digest readily into a non-odorous sludge which has all of the drying characteristics of plain sewage sludge. Gas production rates from four parts of a 50–50 mixture of sewage and food pulp, seeded with one part of digested sludge, were equal to that produced by a mixture of 4 parts of sewage solids and one part digested sludge. Slight increase in carbon dioxide content was noted in the sewage-food gas but the heat value of the total gas would be greater than for sewage alone if the increase in solids available for digestion were taken into consideration.

It was noted that the gas production rate of the sewage-food mixture was reduced after the fifth day. Hydrogen-ion observations indicated that acidic reactions had been set up in the mixture as a natural result of the digestion of the food solids. Adjustment of the pH to 7.0 re-established normal digestion.

The Baltimore tests called attention to the fact that a daily addition of five per cent of raw sewage-garbage was probably the maximum allowable. The writer's tests showed that the sewage-food mixture was, in itself, a satisfactory seeding material. Sludge and sludge-food mixtures, seeded with this new type sludge, digested normally. This ability of sewage-food mixtures to serve as seeding material should make the process of digestion more feasible.

While the addition of pulped food and its normal liquor and flush water to Schenectady raw sewage, in the expected proportions based upon universal discharge of food into sewers, increased the B.O.D. of the raw sewage by about 20 per cent. Imhoff cone tests indicated that the clarified effluent from efficient settling tanks would have no greater B.O.D. than for sewage alone. The proven ability of the waste food solids to coagulate and remove the colloidal sewage solids from suspension, probably explains this reduction in oxygen demand by simple sedimentation.

Other Interesting Phases of the Problem

There are numerous interesting phases of the question of combined collection and disposal of sewage and food wastes, either from the home or from central grinding stations, which merit the open-minded consideration of sewage treatment experts.

Aside from the hygienic considerations which make the instantaneous disposal of waste food at the home of great interest, there are economic questions involved which must eventually be answered. The cost of collection of garbage and its sanitary disposal must be balanced against the cost of treating the additional solids at the treatment works. The value of the additional gas produced and the fertilizer value of the increased quantities of sludge will not be minimized by those who place value upon these characteristics of sludge.

Another interesting field for speculation is the possible advantage of home disposal over mass disposal at central stations, in producing a more uniform sewage flow. The grinding of wastes during collection hours and the discharge of the resultant pulp at points but a short distance removed from the treatment plant may result in sharp changes in sewage character which may upset the plant. The house-to-house discharge of food wastes, the variation in family habits as they apply to time of preparation and eating meals and the well known ironing-out effect of long sewer lines should produce a more uniform and more easily treated sewage.

The entire problem is novel enough to look incapable of solution upon first judgment. The matter, however, has been brought to the attention of the profession in an active manner in the past few months. It is deserving of the unbiased opinion of sewage treatment men. The first need is for the removal of the pressure of precedent from our minds. This should not be difficult, in view of the lightning-like changes in sewage treatment practice of the past decade. Anything is possible; anything can happen.

That poet laureate of plain prose, Chic Sale, laughed the outhouse out of the back yard. Sanitary science may ridicule the garbage can out of the American home. The dual disposal of sewage and waste food opens avenues of advancement for sewage treatment in communities where the construction or reconstruction of a sewage works is not finding public favor. The combination of the ever present problem of garbage disposal with the misunderstood problem of sewage treatment should raise the joint process to the status of a true utility. Show me the operator with soul so dead, who never to himself has said, "Here's hoping."

Discussion

Glenn D. Holmes, *Consulting Engineer, Syracuse, N. Y.:* Mr. Cohn has given us an interesting resumé of his investigation of the possibilities of the dual disposal of sewage and garbage.

Our genial Vice-President has a most delightful and pleasing way of expressing himself and presenting the subject matter under discussion whether it be in the columns of the "Grit Chamber" or when presiding at our "Sunrise Breakfast" or in the presentation of a more serious paper such as he has given us this morning.

How much happier his expression "dual disposal of sewage and food wastes" than sewage and garbage. A rose, you know, by any other name would smell as sweet. Perhaps garbage by another name is not so odorous. Let us hope that he may find a more fragrant name for sewage.

I like the charming way in which he speaks of his beloved old plant as it begins to show obsolescence. "General decadence of the works has long indicated that inexorable old age was creeping on." This brings to mind the poet's description of the declining years of two old maids:

"Two maiden dames of sixty-two
Together long had dwelt.
Neither alas! of love so true
The bitter pang had felt.
But age comes on, they say, apace
To warn us of our death,
And wrinkles mar the fairest face;
At last it stops our breath."

Without doubt the treatment of the sewage and garbage of a community, in a single plant, has many advantages and promises substantial economies if the expectations of its advocates can be realized. Like all new methods of treatment, plant size operation will be necessary to discover and correct the difficulties which are not observed or appreciated in small scale or laboratory demonstration.

Mr. Cohn calls attention to a number of questions which must be answered before home disposal, as he suggests, can be installed or before treatment plants to perform the dual duty can be intelligently designed.

Some years ago Syracuse constructed a Cobwell garbage reduction plant expecting to receive a substantial return from the sale of grease and tankage. The city experienced many troubles in its operation and for some time the Cobwell Company has been operating this plant, and also the rubbish incinerator, under contract. Both of these plants are in proximity to the sewage treatment works.

About two years ago, shortly before a five-year contract was to expire, the speaker and his associate, Mr. Earl F. O'Brien, became interested in the Syracuse problem and after making a study proposed a new and original method of garbage disposal. A brief description of our proposed method may be of interest in this discussion, since it also contemplated pulverizing of the raw garbage and disposal with the sludge from the sewage treatment works.

In connection with our investigation some little consideration was given to a plan even more similar to that described by Mr. Cohn. It included pulverizing the garbage, not at the household, but at the existing garbage plant; digestion with the sewage sludge; collection and utilization of the gas for power and heat at the sewage, garbage and incinerating plants, and at the sewage pumping station.

This plan was very attractive since the estimates indicated that the savings in operating cost of three plants (garbage, rubbish, sewage) would be sufficient to retire all construction bonds within ten years and in addition show an average annual saving during this period of $14,000.

This plan was not submitted to the city administration for their consideration. It was felt that there were too many uncertainties involved. Since our investigation much more has been learned regarding digestion of garbage by the excellent work of Keefer at Baltimore.

You who have visited the Syracuse sewage treatment works will recall that the sludge from the settling tanks is pumped through a 5-inch force main, a distance of about two and one-third miles, for disposal in the lime wastes of the Solvay Process Company.

The method of garbage disposal which we recommended after demonstrating its practicability proposed that the garbage be collected as previously, dumped into the existing receiving pit at the reduction plant, and elevated by the existing conveyor to a new bin placed on the charging floor of the rotary dryers. A chute from this new bin would distribute the garbage in a thin layer on a picking belt driven by a magnetic pulley for removing tramp iron. The garbage would drop from the belt into a hammer-mill and together with diluting liquid, either sewage or sewage sludge, pass through the pulverizer and into a conditioning tank. A centrifugal pump would then deliver the pulverized garbage, now in fluid condition, either to a storage tank or directly to the intake of a triplex pump. This high pressure pump would discharge into the sewage sludge force main and the combined, mixed garbage and sewage solids would be transported to the waste lagoons for disposal in the same inoffensive, economical manner that has been employed successfully during the past decade.

This plan had numerous advantages in addition to a remarkably low installation and operating cost.

The new equipment could be installed in a very small portion of one of the existing buildings, releasing desirable space for other municipal use. No new housing would be required. The existing plant could be operated with little interference to the old process of reduction while new equipment was being installed. The proposed plant would require less skilled operating personnel.

The contract for operating the reduction plant included a payment of $36,000 per year or $180,000 for the five-year period.

Estimates for the proposed plans indicated an average saving of $12,000 per year, for the first five years, in addition to paying the entire installation cost. These figures were based on the old contract price for operating the existing plant.

The city administration was interested in our proposed plan, realizing that operating costs would be much greater after expiration of the contract. Interested parties, however, endeavored to discredit our recommendations. A report was submitted to the mayor endeavoring to prove that raw garbage could not be ground fine enough for pumping through the existing 5-inch sludge main; that friction losses in pumping would require the installation of a new 10 or 12-inch main at great cost; and that for this larger main a 600 horsepower motor would be necessary. The existing sludge pump motors were 15 horsepower, which were estimated as ample for the new service. These were only a few of the arguments advanced in an effort to prevent further consideration of our plan.

No records were available for garbage having been pumped any particular distance or through so small a pipe line. We had accumulated sufficient information, however, to know that garbage could be pulverized without difficulty and had conducted experimental laboratory tests which indicated that friction losses in pumping garbage would be less than for sewage sludge of the same moisture content. Records of the quantity of garbage collected and the report of the sewage treatment plant enabled the making of computations showing the total combined daily quantity of dry garbage or sewage solids for the preceding four years.

Our suggestion to demonstrate and prove the soundness of the proposed method was accepted by the city.

A small hammer-mill for pulverizing garbage was loaned us by the Jeffrey Manufacturing Company of Columbus, Ohio, and set on an elevated platform in such position as to discharge into the body of an old garbage collection wagon recovered from the dump. The Morse Pump Company of Baldwinsville kindly loaned us a small centrifugal pump which was connected to the discharge the ground garbage through about 100 feet of 4-inch pipe to one of the sewage settling tanks. This tank had been drained and temporarily placed out of commission for the demonstration. Two motors for the pulverizer and pump were rented for a nominal price. A snow loader was loaned by the Department of Public Works for elevating raw garbage from the ground level to the platform supporting the hammer-mill. Mr. Gyatt, superintendent of the Bureau of Sewage Disposal, rendered valuable assistance in installation of equipment. The necessary labor was supplied by the Work Relief Bureau. The city engineer's office supplied supervisory control of the labor and witnessed the performance of operation and results.

The demonstration included practically all steps in the process proposed with the exception of hand picking of trash from a moving belt which is being done in many other plants. The particular features requiring demonstration were:

1. Pulverizing the garbage.
2. Handling the ground garbage without difficulty with small centrifugal pumps for conditioning.
3. Pumping the pulverized garbage with the existing sewage sludge pumps and forcing through the two-mile 5-inch force main without overloading the 15 H.P. motors.
4. Effect on the disposal lagoons of discharging garbage solids thereon.
5. Possible effect on the sanitary condition of Onondaga Lake.

It was our hope and expectation to be able to pulverize about two tons of garbage per hour with the small hammer-mill and to accumulate a quantity of the ground product in the sewage settling tank for tests of the triplex pumps, motors and force main.

After a few trial runs and minor alterations of the set-up, much to our surprise we were able to pulverize, with this small machine, 6 to 7 tons per hour. Apparently the demonstration was proceeding too well. The company operating the garbage plant made complaint that too little garbage was left to permit keeping the plant in service. It insisted that either less garbage be taken or the reduction plant would be shut down, in which case it would be necessary for our demonstation plant to dispose of all of the garbage from the city, each day, as delivered.

The reduction plant was shut down for one week. Two shifts of Work Relief men were obtained and all of the garbage collected from the entire city was passed through the demonstration plant. The mechanical details of the proposed method of operation were demonstrated beyond question and to the entire satisfaction of the city administration.

But—history records the same cruel rejection experienced by the Schenectady proposal. If you are interested in the reason, let me add, it was purely a question of expediency.

Mr. Cohn suggests several questions for discussion—

First. Would a simple home disposal unit be practicable? This question I believe can be answered in the affirmative in so far as it relates to the mechanical equipment. It is doubtful, however, if the housewife will react favorably to the suggestion for its use.

The total cost of the many individual units for household equipment would quite likely exceed the cost of a municipal plant for pulverizing or pumping to digestion tanks.

Second. Would the house plumbing pass the wastes? I believe little trouble would be experienced if food wastes only are discharged into the sewer after fine grinding. There is likely to be more frequent trouble due to stoppages from the additional grease.

Third. Would the sanitary sewers carry the new type sewage-food mixture? Yes, providing the wastes are finely pulverized and all materials other than food are rigidly excluded and provided the sewers themselves are in good alignment, and laid on grades insuring a reasonable velocity.

Municipal garbage contains considerable material which although easily pulverized would be unsuitable for discharge into sanitary sewers or to digestion tanks. In our demonstration work we removed, after pulverizing, large quantities of metal bottle caps, broken bone, egg and oyster shells, china and glass ware. Any of this material might easily cause trouble.

Fourth. Other questions suggested relate to treatment of the new type sewage and can be answered only after plant scale operation and demonstration.

We trust Mr. Cohn will continue his investigations of this interesting problem. It is a pleasure to assure him of our appreciation and to thank him for the advance information regarding dual disposal of sewage and food wastes.

MECHANICAL EQUIPMENT IN SEWAGE TREATMENT*

By Charles C. Agar

Assistant Sanitary Engineer, New York State Department of Health, Albany

Mechanical equipment in sewage treatment is not new, for it is reported that mechanical rakes for bar screens were in use at Paris about 1867 and in England since 1890. But it is only during the past decade that great strides have been made in incorporating mechanical devices in sewage treatment plants.

Mechanical equipment may be designated as any device with moving parts which performs or assists in carrying out any of the necesasry steps in a treatment process. In this category we should logically include pumps, but for the purpose of this discussion I will refer only to the types of equipment which provide some measure of treatment of the sewage. Incidentally there are at least 52 muncipalities, of some 160 having treatment plants in New York State, where all or the greater part of the sewage is pumped during either collection or treatment.

In order to justify the use of mechanical equipment in a sewage treatment plant we must be able to show that it has definite advantages, keeping in mind that the purpose of sewage treatment in any municipality is to attain certain objectives which depend on the local requirements. These advantages may be one or more of the following:

1. Performance of the same work more economically than with non-mechanical processes.
2. Higher efficiencies of treatment or more satisfactory results at a cost comparable with non-mechanical processes.
3. More positive functioning of treatment processes.

In the last analysis it is a question of the cost per unit of accomplishment or work done. I believe it is true that the mechanical equipment of today has been designed with this purpose in view. It does work efficiently and effectively. We can appreciate readily the laborious and disagreeable task of removing sludge from the old flat-bottomed settling tanks by squeegees, water and man power. What a contrast to observe the operation of modern mechanical equipment for the removal of sludge from plain settling tanks.

There is no doubt that mechanical equipment has come into the field to stay and with this change must come a grade of operator able to operate and maintain the equipment. As with any type of mechanism, mechanical equipment used in sewage works must be oiled, adjusted and

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repaired as occasion demands. The necessity of having a competent operator should insure more careful operation and attention than may occur in the case of the non-mechanical or so-called "fool-proof" plants, that are referred to even today by some consulting engineers. I have yet to find one of these plants fool-proof in fact.

Obviously I cannot enter into a discussion of the relative merits of various types of equipment. In general all types perform the work for which they were designed in a satisfactory manner.

Mechanical equipment has been in operation for a sufficient length of time to indicate where improvements are necessary. Manufacturers must profit by operating experiences in order to maintain mechanical equipment in its present enviable position in the sewage treatment field. Ruggedness and simplicity of construction are desirable in order that the repair shop may not become the busiest part of the treatment plant. The ease of access to the equipment or of its removal for repairs are also important factors.

Inasmuch as mechanical equipment is installed for a definite purpose it must be dependable and able to operate continuously. Have we considered what must be done to make replacements or repairs? We cannot tolerate the use of the plant by-pass except in cases of dire necessity. This emphasizes the importance of maintaining at the plant a stock of the usual replacement parts. It is also desirable to provide greater flexibility in operation by installing duplicate units. For example, where one large settling tank might provide adequate settling facilities, the installation of two smaller units may be worth the small increase in cost because of greater assurance of at least partial operation.

During the past few years there has been a decided trend toward the use of mechanical equipment in the sewage treatment plants of New York State. A brief review of the plants in operation will indicate the present status of mechanical equipment and a resumé of installations proposed will emphasize the growing recognition of mechanical devices as an aid in sewage treatment.

There are in New York State some 190 municipal sewage treatment plants. Mechanically cleaned bar screens are in use at six of these plants. Fine screens of the disc, drum, or belt type are employed in 15 plants, eight of which are in the City of New York and five in Westchester County. There are seven mechanically cleaned grit chambers and eleven primary settling tank installations equipped with mechanical sludge removal equipment. Mechanically stirred digestion tanks number three. There is one activated sludge plant in which combined air and mechanical aeration is used. No revolving or traveling distributors are in use at municipal plants.

Among state institution plants three have mechanical bar screens and one has revolving drum screens. There are two plants with mechanical primary sludge removal equipment and two with stirring devices for separate digestion tanks. Two plants have revolving distributors for trickling filters. The only activated sludge plant at a state institution is equipped with mechanical aerators.

Plans for 33 municipal sewage treatment plants have been submitted to the New York State Department of Health for approval during the past two or three years. The following classification of the types of mechanical equipment incorporated in these plans shows a significant trend toward mechanization of treatment processes.

Mechanical Units	*Number of Plants*
Bar screens	10
Fine screens	3
Grit chambers	3
Settling tanks	23
Digestion tanks	9
Trickling filters	2
Activated sludge	1
Vacuum filters	3

Of the three plants employing vacuum filters, two will use the filter for chemically treated sludge. The third will use filters for sludge treated with chemicals, and for the settling tank effluent, using paper pulp as a filter medium.

Among the proposed plants there are only seven Imhoff tank installations, two of which have some mechanical equipment.

Looking into the future I foresee even greater use of mechanical equipment to facilitate the treatment of sewage. This is true not only because of advantages referred to above but also because of the renewed interest in chemical treatment of sewage. Modern chemical treatment implies the use of mechanical equipment for chemical feeding, mixing, and sludge handling. It is not alone sufficient to add the necessary chemicals to the sewage, but such addition must be made in regulated doses and proper mixing must be provided. Just as we have learned in water treatment that the best coagulation is obtained under certain physical conditions of mixing and stirring, so must we apply similar principles to the chemical treatment of sewage in order to keep the costs within reasonable limits. One of the chief causes of failure of chemical treatment processes in the past has been the lack of proper mechanical equipment for making relatively small doses of chemicals effective.

More widespread use of chemical treatment processes is to be expected, particularly in those localities where the need for an additional degree of treatment is only seasonal. However, in localities where a high degree of treatment is necessary throughout the year, we cannot at this time expect that chemical treatment processes can replace proven biological processes for secondary treatment.

We may also expect increased use of mechanical distributors on trickling filter units. Under many conditions, particularly where a saving in head is desirable, this equipment has advantages.

The disposal of screenings from the bar rack presents a problem for the plant operator both in winter and summer. Frozen screenings and lack of burial facilities in winter, and flies, rats, and odors in summer, emphasize the deficiencies of this part of the plant. What is needed is not only a mechanical rake for removing the screenings from the bars, but also a device for disposing of the screenings produced. One school of thought clings to the principle that anything taken out of the sewage should be removed and disposed of separately. There is, however, another solution of the screenings disposal problem, namely maceration and return of screenings to the sewage entering the plant. When we stop to consider that the main purpose of screens is to protect pumps, sludge lines and channels from clogging we can appreciate the logic of the latter method.

Another field in which improvement may be expected relates to the final disposal of sewage sludge. It is generally recognized that sludge has value as a compost, soil conditioner or fertilizer but the main handicap to its use appears to be the physical form in which it is available. Lumps of sludge removed from the drying bed are not easily handled, but if ground or pulverized there is no reason why a ready market cannot be established. We should see greater use of mechanical equipment for this desirable processing.

In the field of sludge handling we may also expect to see the use of mechanical devices for dewatering the sludges produced by all types of plants. At this time the vacuum filter appears to be on a competing basis with sand beds at large plants, with promise of economical operation at smaller plants as refinements are developed.

It may be concluded that mechanical equipment is being given an opportunity to prove its value in the sewage treatment field. Many of the devices have demonstrated their value through several years' operation. Some of the equipment has not been subjected to tests or the ravages of sewage, sewage gases, and the elements for a period long enough to be able to evaluate its true worth. However, the equipment in operation today is in general performing satisfactorily the work for which it was designed. Because of the general improvement in the results obtainable at plants mechanically equipped, we may anticipate greater use of such equipment in the future.

THE INCINERATION OF SEWAGE SOLIDS*

By A. E. Stilson

Morse-Boulger Destructor Company, New York City

Incineration has recently come to the fore as a means of disposing of sewage solids. The fuel requirements, the method of dehydrating and handling various kinds of sewage wastes must be modified in accordance with the quantities expected. In practice we have found that one million gallons of flow produces

(*a*) 100 to 150 pounds of 82 per cent moisture coarse screenings
(*b*) 700 to 1000 pounds of 82 per cent moisture fine screenings
(*c*) 1800 to 2500 pounds of settled sludge solids on dry basis (18 to 25 tons at 95 per cent moisture)

Where mechanical methods of cleaning the screens or thickening the sludge are used the weights obtained range to the high side.

The value of dehydration before incineration is obvious. Under some conditions it may be badly over-emphasized. In plants handling less than five m.g.d. the amounts of fuel required are apt to be so small that filters for sludge, centrifuges for any type of solid, or mechanical presses make the operation more expensive, all things considered. In plants handling from five to ten m.g.d. there is an indeterminate dividing line, on one side of which the use of mechanical dehydration is found to be economically justified, provided simplicity is rigidly practised in designing.

In plants of more than ten m.g.d. mechanical dehydration before incineration should and can be applied to advantage. This is increasingly true in plants of more than twenty m.g.d. capacity. The type of unit used for the purpose will vary with the material to be dealt with as follows:

(*a*) Coarse bar screenings will drain if allowed to stand in small batches in a proper receptacle, such as a perforated can of not over two cubic-foot capacity. Larger batches do not drain as well as the smaller. A batch press of the mechanical or hand screw type is useful but not strongly recommended.

(*b*) Fine screenings may be dehydrated by idler roll, belt wringers to about 75 per cent water content; by driven roll, driven screen, presses, to about 70 per cent; or by batch centrifuges down to 60 or 65 per cent. The power, labor and chemical costs, if chemicals are used, for the purpose of drying fine screenings below 65 per cent moisture are at present unjustified, by comparison with the fuel costs indicated.

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* Presented at the Spring Meeting of the New York State Sewage Works Association, Jamestown, June 15–16, 1934.

(*c*) Grit in quantity is easily and effectively centrifuged to 60 or 65 per cent water content. Continuous presses are badly abraded by the sharp hard particles in the grit. Grit drains naturally and readily to a surprising degree.

(*d*) Skimmings, scums, and greases may be concentrated by separatory decantation to various moisture contents ranging from 75 per cent down.

(*e*) Sludge, depending upon how produced, treated and mixed, may be filtered on vacuum filters to various degrees of moisture, as follows:

Raw sludge fresh, between 83 and 75 per cent.
Activated sludge, between 83 and 79 per cent.
Digested sludge, between 75 and 70 per cent.
Chemical sludge, between 65 and 58 per cent.

Centrifuges, decantation, chemical and bacteriological separation as other means of dehydration for sludges are known, in fact, but unknown in practice on a large scale.

Since dehydration of fine screenings is rather important, a brief description of each of three types of dewatering equipment is pertinent. Idler roll, belt wringers are used and may be seen in the three new Westchester plants. A rubber conveyor belt passes between opposed rubber-tired wheels carrying the screenings continuously to and from the pressure point. Water drains off the sides of the belt. The devices, as perfected in Westchester, are simple and dependable, which are two of the most important factors in good design. The operating costs, as a result, are low and the results are reasonably uniform.

In Milwaukee the centrifuge basket and motor, as a unit, float freely, eliminating vibration. Controlled batch feeding from and by ejectors is accomplished through manually operated valves. Batch unloading is made possible by means of an electric hoist which lifts, travels with, and empties the basket and finally returns the basket to place. The basket tips to dump the batch into a lorry. Electric alarms and indicators give the operators all necessary information for proper operation. Continuous loading and unloading of the centrifuge was studied but discarded by the Milwaukee Commission as not yet feasible. The centrifuged cake from a Milwaukee batch varies in its moisture content directly as the thickness of the cake produced. Best results are obtained when the mat deposited on the perimeter is not over about five inches in thickness. Grit and fine screenings were mixed at the time of the tests. In my opinion grit or screenings should be dewatered separately.

The driven roll, driven screen belt, continuous roll press installed at Los Angeles is a very satisfactory dewatering device for fine screenings. It consists of four or more sets of opposed, driven metal rolls between which a copper bronze wire screen is driven which conveys a uniform volume of fine screenings to the rolls. The degree of pressing is graduated to a maximum under the fourth pair of rolls. Each consecutive roller after pressing out the screenings kicks or fluffs them up into a little loose pile in front of the next succeeding pair of rollers. It is surprising how much water may be easily and uniformly removed from a loose pile of screenings by only comparatively light pressing.

Sludge concentration by vacuum filters is a valuable adjunct to further drying and final incineration. The functioning of the various types of vacuum filter has been well described in current literature and need not be described here. The continuity of operation and the dependability possible with a vacuum filter are of major importance in a sludge incineration project. It must be remembered that the reduction of moisture from a thin slurry to a cake, that can be handled, is really the greatest hazard to be conquered in sludge drying and burning. If other means of concentrating the slurry are used they must give an end result in the form of a uniform and continuous cake, or equal.

Dehydration as a part of handling has so far been discussed. In a large sense, however, it is only one important part in the step termed handling. The methods used in storing, conveying, or charging the material into the incinerator are equally important. Experience shows the following data to be of value.

(*a*) Coarse bar screenings should be handled and charged into the incinerator in small batches. They should not be stored in hopper bottom bins. Coarse bar screenings mat together in snarls and will clog dewatering devices, conveying mechanisms, automatic charging doors, or incinerator feeding arrangements and they are hard to stoke or break up in the incinerator.

(*b*) Fine screenings as dry as 82 per cent moisture may be handled in ejectors and pipe lines. They can be stored in ejector pots or gravity discharge hopper bottom bins, provided they are not allowed to stand for long periods of time. Rubber conveyor belts are neither truly sanitary nor entirely satisfactory. Fine screenings that are drier than 82 per cent will mat, pack and bridge badly and are hard to remove from a closed hopper bottom bin. If mechanical conveyances for dry screenings are necessary, dump cars or rubber conveyors are best. Fine screenings if heated expand rapidly. Dehydration likewise reduces the unit weight per unit volume beyond normal expectations. At Milwaukee the estimated weight of cold screenings per cubic foot was 45 pounds at a moisture content of 60 to 65 per cent. Actually the weight was 33 to 38 pounds cold and, when heated, reduced to an estimated weight of 28 pounds. In Westchester County the bridging across the hopper bottom charging gate seemed to be aggravated by the small amount of heat radiated from the top of the incinerators. In designing the plant at Milwaukee, a charging floor was used. If closed bins had been used serious difficulty would have resulted. At Los Angeles the bin for the dehydrated screenings is entirely open on one side with provision for a man to charge the incinerator through the open side without becoming fouled.

Sludge handling and storage is a subject by itself. Hourly, day to day, and seasonal variations in the nature of the material preclude the possibility of accurate moisture control. Handling devices must therefore be capable of readily accommodating themselves to the various consistencies without manipulation or attendance. Heated filter discharge aprons are used in Milwaukee to produce a steamfilm between the metal and the cake. Brick oil and scrapers are used on the belts. In other places steel ribbon flight conveyors are used. The comparative degree of difficulty experienced in handling different types of sludges is not known to be dependent upon the type of treatment. Digested Imhoff sludge from drying beds in one case is known to be more difficult to handle than raw and activated sludge. The bed-dried Imhoff sludge was added in this instance to help but it hindered.

After handling sludge from a filter, to store it without first drying it down to a loose powdery mass is to invite trouble from slumping and compacting into a stiff mortar-like consistency. If dry, powdery sludge is to be stored, great care must be exercised to ventilate the powder, keep it dry and cool. Failure in so doing may mean fire of a serious nature. Sludge powder may be highly explosive and dangerous under certain conditions.

So far, emphasis has been put on the dewatering, handling and storage of sewage wastes preparatory to incineration.

Incineration is a process of rapidly oxidizing organic carbon and/or carbohydrates to odorless, inert and colorless gases and ash. The chemical and physical laws common to all combustion processes govern incineration. The character and composition of the material to be burned are of primary importance. Approximate analyses of various waste substances are given in Table I. It will be seen that there is little or no value in fact represented by the column headed "Heat Value as Received." This column is included only because it will demonstrate why the combustion engineer disregards it. Volatile carbon and fixed carbon are necessarily treated as separate entities from a combustion standpoint. Merely knowing the amount of loss on ignition seriously handicaps incinerator design. Fixed carbon requires but 11.5 pounds of air for combustion. Volatile carbon, or the hydrocarbons in some cases, theoretically demand as much as 14 or 15 pounds. If too little air is allowed

Table I.—*Approximate Values of Various Waste Substances*

Substance	Wet Basis as Received					Average	Average
	Combust.		Ash	H_2O	Heat Value	Heat Value, Ash & Moisture Free	Theoretical Air Req'd, Ash & Moisture Free
	Fixed C.	Vol. C.					
Municipal Garbage	5%	18%	12%	65%	1930	8500	12.5#
Municipal Rubbish	40%	40%	12%	8%	7230	9000	13.5#
Coarse Bar Screenings	2%	14%	2%	82%	1340	8500	12.5#
Fine Screenings	2%	13%	3%	82%	1260	8500	12.5#
Grit	2%	16%	12%	70%	1600	9000	13.5#
Raw Filtered Sludge	1%	13%	6%	80%	1680	12000	14#
Activated Filtered Sludge	1.5%	10.5%	6%	82%	1320	11000	13.5#
Digested Filtered Sludge	3%	17%	7%	73%	2000	10000	13#
Chem. Laughlin Filtered Sludge	1%	18%	16%	65%	2180	11500	14#

for in design there will be smoke, soot, odor and nuisance. Too much air will result in a cold furnace and odor or smoke.

In designing an incinerator definite temperatures are sought. Table II gives the approximate ignition temperature for various organic substances. Note that 1250° F. is about the minimum temperature at which odors can be expected to burn, and that 1490° is the upper necessary temperature, but it is safe to use 1250° as the basis for preparing heat balances for incineration. A heat balance is based on the fact that energy cannot be destroyed and takes into account only initial and final temperatures, specific heats or latent heats of material and the quantities of heat available or necessary to do a predetermined job under definite conditions.

Depending upon the quantity of material to be burned and the moisture content, an efficient dryer may or may not be required. In plants of 20 m.g.d. or over, if sludge is to be burned a dryer is indicated. Theoretically, when using a properly designed dryer and given a small amount of digestor gas, or other energy to produce electrical power, the dryer will make it possible, in my opinion, to incinerate even an 83 per cent wet raw sludge satisfactorily without fuel.

Time does not permit a discussion of the principles of sludge drying. (See *Public Works* for May, June and July, 1934.) Reliable information from several sources, and tests, confirm the opinion of Dr. Rudolfs

TABLE II.—*Ignition Temperatures of Various Substances*

Substance	Deg. F.
Hydrogen H	1076–1094
Carbon Monoxide CO	1191–1216
Ethane C_2H_6	968–1166
Propane C_3H_8	
Ethylene C_2H_4	1008–1018
Acetylene C_2H_2	763–824
Hexane C_6H_{14}	909
Decane $C_{10}H_{22}$	865
Benzol C_6H_6	1364
Toluol $CH_3C_6H_5$	1490
Ethyl Alcohol C_2H_5OH	1036
Propyl Alcohol $CH_3CH_2CH_2OH$	941
Isopropyl Alcohol $CH_3CH(OH)CH_3$	1094
Butyl Alcohol $CH_3(CH_2)_2CH_2OH$	842
Methyl Alcohol CH_3OH	768
Ethyl Ether $C_2H_5OC_2H_5$	649
Cylinder Oil	785
Penn'a Crude	601
Gas Oil	637
Kerosene	563
Acetaldehyde	365

and others, that high temperature drying and the heating of all dryer discharge gases to or above 1250° F. is unnecessary. Experience now proves that sludge may be dried to 20 per cent moisture content without odor, provided the material is not heated above 100° F. and it is my opinion that even the dryer exhaust without heating to 1250° F. will not contain objectionable odors. This fact means that comparatively simple, and non-sensitive, low-temperature air, sludge dryers are available for any sludge cake that can be handled as a solid.

Once the material, be it screenings, grit or sludge, is ready to be burned it must flow to the incinerator for firing at a uniform and continuous rate, or furnace temperatures may fluctuate dangerously. At low temperatures the ash is not clean, the chimney is smoky and odor is produced. At overloads, unusually high furnace temperatures, slagging of the ash, choking of the chimney and dirty fires with worn out men and furnaces result. Of course, the furnace must be properly designed.

If a furnace is to burn coarse screenings only, a standard wet garbage incinerator designed for auxiliary fuel will be adequate. A fine screenings destructor would, of course, also take care of the coarse screenings. This incinerator, however, should be particularly designed for its job. At most, the grate areas should receive no more than 25 to 28 pounds of wet screenings per hour. The fuel burners should, wherever possible, send a blast of flame against the screenings. If coal is used, except in very small installations, it should be burned as a powdered fuel for economy. Digestor gas is very good as a fuel but should be delivered under pressure of from 10 to 16 ounces, unless expensive equipment such as high pressure blowers is available. Forced draft is nearly useless with wet screenings due to their tendency to mat. Screenings burn from the surface down. Frequent and regular stoking is desirable to break up the carbon and ash formation, that otherwise forms an insulator. The quantity of ash is small and does not need special provision for removal. Cast iron being a base metal may be badly slagged even at 1200° to 1400° F. by the ash, which is silica and very acid. Milwaukee tests conclusively proved that when burning screenings and grit at the rate of one ton per hour, cast-iron grates were useless within seven hours. No cast-iron parts are used that can be reached by slag at Westchester, Los Angeles or Milwaukee. Skimmings, scums and greases should not be introduced directly into any furnace in large batches. Grit may be burned without difficulty to a clean sand in a well designed screenings destructor. If large amounts of grit are to be expected the burning rate per square foot of grate area should be decreased accordingly to accommodate the sand and ash accumulation.

A sludge incinerator can take care of the screenings from the plant, provided the screenings are fed in slowly. Sludge destructors, however, should be proportioned, constructed and equipped for a more difficult task. The quantities, if large enough to warrant a destructor, are usually sufficient to justify stokers or other mechanical firing equipment, using preheaters, forced draft fans and mechanical ash removal with fly ash collectors. The indicated temperatures resulting from sludge incineration are higher than for screenings. In addition, carbon dioxide and ash entrained in the dry sludge will do surprising things as a fire extinguisher. To be efficient from a fuel standpoint, the incinerator should be built in conjunction with a dryer. This desire to use the waste heat causes considerable change in the furnace design, not only to make possible waste heat recovery but to care for the large volumes of air necessary in the drying stages. To date there are very few, if any sludge destructors in regular operation. Experiments, however, have proven that they are practical.

Discussion

W. H. Pitkin, *Oliver United Filters, Inc.:* Experience has indicated that dewatering of sewage sludges by known methods does not reduce moisture content sufficiently to allow economical and efficient incineration without further dewatering by evaporation.

The trend has been away from the present methods of evaporation in rotary dryers due to the difficulty of maintaining sufficiently accurate temperatures during the long drying cycle and to the inherent rotary action of this type of dryer with its effect upon the physical character of the sludge being dried.

Unsatisfactory temperature control produces offensive odors during drying by scorching the smaller particles. The rolling motion of the material in the dryer causes the formation of larger particles which tend to "case harden" and hence insulate the undried center portion.

For these reasons two different schools of thought have developed in the attack on this problem: first, drying at such low temperatures that offensive odors are not produced, and second, flash drying with extremely short contact at high temperatures.

In our opinion low temperature drying has the following advantages:

1. Accurate temperature control with large volumes of low temperature air resulting in maintenance of the material at a temperature below which offensive odors are produced.
2. Maintenance of constant surface area exposed for drying because material lies undisturbed during the entire drying cycle. This produces a more uniformily dried product.
3. Dried material can be stored before incineration thereby allowing the incinerator to operate at a uniform rate independent of the dryer. It is not feasible to store dewatered sludge ahead of the dryer, therefore this storage is very important for flexibility of operation.
4. Drying air may be exhausted without offensive odors thereby avoiding the necessity of raising this air with its moisture to temperatures high enough to burn the odors produced.

William Raisch, *Municipal Sanitary Service Corp., New York City:* During recent years continuous vacuum rotary filters have been used extensively for dewatering sludges to produce a sludge cake containing between 60 and 80 per cent moisture. Sludge at this moisture content, while it can be readily burned in an incinerator will not offer self-sustained combustion without nuisance. For this reason considerable thought has been given to various forms of drying and apparently Mr. Stilson and others believe that low temperature drying, between 95° and 125° F. is a possibility. Although low temperature drying has been used in the industries it has been applied principally to foods and mineral solids of the pigment type having constant characteristics. While experimental work may have been done in low temperature drying of sewage solids I know of no plant using the method on an operating scale.

In the recent articles by the same author and referred to in his paper, a theoretical composition of sludge has been used, as an example, which is much nearer the ideal than most sludges produced. If sludge of consistent characteristics can be produced day after day without sacrificing the efficiency of the treatment plant, low temperature drying might be justified, but this is not the case, as the sludge produced in various plants will vary, and even the sludge from the same plant may vary from day to day depending upon industrial wastes.

It is my opinion that self-sustained incineration can be brought about only if the preliminary methods of drying or dewatering are mechanical and not of the heat transfer type. Those of us interested in mechanical filtration and dewatering by means of continuous vacuum filters have endeavored to lower and have succeeded to some extent in lowering the moisture content of the sludge discharged from vacuum filters. An obstacle remains, however, which applies to heat transfer methods as well as to mechanical methods of drying. In dewatering sludge by filtration or other methods of concentration, chemicals must be brought into play, and these chemicals tend to reduce the calorific value of each pound of dried sludge to points far below the content of the ash-free and moisture-free sludge named in the author's paper. In order to overcome this obstacle, Mr. Arthur Wright and the speaker have developed methods for the use of a material containing calorific value as a substitute for the chemicals. To date this substitute has consisted of a paper pulp, obtained by shredding waste paper. Although Mr. Stilson infers in one of his recent articles that a paper pulp has a detrimental effect his implication is unfounded, in my opinion, for if lime were used instead of paper pulp, the reduction in calorific value would be much greater.

Mr. Stilson also points out that each incinerator should be designed particularly for each project and that the grate areas should be equivalent, in the case of screenings, to one square foot for each 25 or 28 pounds of material burned per hour. He further states that fuel burners should direct the blast of flame against the screenings, that screenings burn from the surface down, and that forced draft is of little use. This may be true in certain furnaces having solid hearths or grates, but in the case of furnaces equipped to hold the material in suspension, the flame may be directed against both the top and bottom; using forced draft to advantage, with the result that better efficiencies and higher rates of burning per square foot are obtained. It is also pointed out that the ash resulting from screenings or sludge incineration is detrimental to iron parts. This may or may not be true in actual practice, although iron has been used in furnaces for the destruction of this and other municipal wastes for many years with satisfactory results.

In conclusion I agree thoroughly with the practice of combining sewage solids with other municipal wastes and burning them in a combination furnace. Work in this direction will bring us nearer to the solution of the problem of self-sustained combustion. I base this contention on trial operation of a municipal plant where relatively large amounts of filtered sludge cake were mixed with the day's run of garbage and trash and the combination successfully consumed without auxiliary fuel under extremely adverse conditions.

SEPARATE SLUDGE DIGESTION TANKS AND THEIR OPERATION *

By W. B. Walraven

Engineer, Springfield Sanitary District, Springfield Illinois

The accepted conception of a separate sludge digestion tank is a room or compartment into which settled sewage solids are placed, away and apart from the sewage or settling tanks. If left to themselves, under proper anaerobic conditions, the solids will undergo bacterial decomposition, the results of which are partial liquefaction and gasification of the volatile matter, and a partial breaking of the bond which holds the solids in aqueous solution or colloidal suspension. These things occur slowly in nature, and it is the province of the sewage treatment specialist to hasten the natural processes by providing the necessary artificial environment.

Facilities at Springfield.—The sewage treatment plant at Springfield, Illinois, receives the sewage from a connected tributary population of about 70,000 inhabitants. During the past four years the flow has averaged 7.0 million gallons per day, with the usual wide fluctuations common to a combined sewerage system. There are no major industries contributing trade wastes. The sewage is settled in primary tanks and given secondary treatment by the activated sludge process. The excess activated sludge is returned to the incoming sewage and resettled in the primary tanks. The mixture of primary and activated sludge drawn from these tanks is discharged to the digestion tanks. The digestion tanks are 41 feet in diameter and 34 feet deep, measured from the rim down to the conical hopper bottom, and each provides about 28,000 cubic feet of available capacity. We now operate four tanks as primary digestors, and two as digested sludge storage holders. Three of the primary digestors are covered with floating covers and the fourth is covered with a gravity type gas holder. All four are provided with adequate heating coils. The two sludge storage tanks are uncovered and usually are not heated.

Starting Digestion Tanks.—The most difficult period of operation ordinarily occurs when the tank is first placed in service. When sewage solids are placed in a tank containing no digested sludge, they first undergo an acid fermentation. The sludge becomes yellowish-green in color, is usually of pasty consistency, and gives off most disagreeable odors. In time the action proceeds to an alkaline digestion stage due to the presence of certain bacterial organisms which have managed to exist, multiply, and finally predominate. The proper way to start a digestion tank is to fill it partially with actively digesting sludge from some other tank, maintain the temperature to which the seeding organisms were accustomed, and fill the tank very slowly with fresh material, adding each day not more than perhaps a tenth of the solids then in the tank. It is likewise desirable to mix the incoming raw sludge with the partially or completely digested sludge. If there is no digestion tank in the vicinity from which to obtain seeding material, the operator might try introducing a few loads of the soft sludge to be found in the bed of a badly polluted stream. If this is considered too much work, seeding material can be generated within the tank from the raw sludge, provided the operator keeps in mind that it may take more than a month to build up properly digesting sludge. He should put only small quantities of raw sludge into the tank, and by all means not count upon filling the tank more than half full during the first four or five weeks. Even this length of time is insufficient in cold weather unless provisions are made to heat the sludge continuously to a temperature which may range from perhaps 80° to 100° F. This can be accomplished either by means of hot water coils or live steam. In the latter case, care must be taken to prevent overheating. Although we did not make any effort at Springfield to control the balance between acidity or alkalinity during the time of initial sludge ripening, it is nevertheless good practice. Daily tests might be taken to determine the pH of the sludge, and if found to be below 6.5, it may be corrected to perhaps 6.8 or 7.0 by the addition of lime. After alkaline digestion has been established the tank is ready for service.

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* Presented before the Eighth Ohio Conference on Sewage Treatment, Columbus, October 5, 1934.

Required Capacity.—The range of capacity for separate digestion tanks is brought out by an examination of the figures for the following Illinois plants, all of which are of relatively recent design and all of which receive sewage classed generally as domestic.

Plant	Digestors Receive Solids From		Digestion Capacity—Cu. Ft. per Capita		
	Primary Settling Tanks	Secondary Settling Tanks	1st Stage	Storage	Total
Aurora	yes	no	2.32	0.00	2.32
DeKalb	yes	yes	2.44	2.44	4.88
Galesburg	yes	no	2.24	0.00	2.24
Rockford	yes	no	1.15	2.67	3.82
Springfield	yes	yes	1.60	0.80	2.40

We have had very good results at Springfield with well heated tanks receiving primary and activated sludge. Operation problems would be simplified if the capacities were more liberal, but we might get along with even smaller tanks by exercising more skillful supervision.

Sludge Temperature.—With regard to the proper temperature at which to maintain the sludge, we have undergone a change of feeling. Whereas we formerly kept the temperature between 80° and 85° F., we now try to keep it between 95° and 100° F. There are certain types of organisms that thrive well at temperatures varying from 70° to 110° F. but are killed at higher temperatures, yielding place to the sewage type of thermophilic or heat-loving bacteria which can thrive only at temperatures from say 115° to 135° F. There is some question as to the practicability of satisfactorily operating with thermophilic digestion, but some interesting and important work is being done in the thermophilic range. It has been found from experience that digestion proceeds more rapidly with increases in temperature, therefore it appears that a tank maintained at 95° F. need not be as large as one maintained at 75° F. We note that many operators have found an increase in the total yield of gas per pound of solids digested at the higher temperatures.

Proportion of Raw and Digesting Solids.—It would be interesting and valuable to know the proper amount of raw sludge that can be added daily in proportion to the amount of semi-digested sludge in the tank. Some authorities think that the daily accretions should not exceed one-seventh the weight of digesting sludge. The Springfield data for the first eight months of 1934 are as follows:

TABLE I.—*Springfield Sewage Treatment Plant*
Sludge Pumped Into Digestion Tanks

Month 1934	Average Gallons per Day
January	30,950
February	31,370
March	37,200
April	37,940
May	39,890
June	45,040
July	48,900
August	52,540
Average	40,850

The volume of solids is not the governing factor, the true measure being of course the weight of dry solids. We pump raw sludge into one tank for a period of two days, and then into another tank for a like period. With four tanks in service, each one is being filled during two days and then allowed to rest six. Before pumping into a tank we provide space either by bleeding off supernatant liquor or by removing sludge from the bottom hopper. The effective capacity of each tank being 28,000 cu. ft., there are about 210,000 gallons, minus two days pumpage, or 128,000 gallons of digesting material in a tank before the refill period. This is approximately three times the volume of the daily accretion or one and one-half times the two days accretion. Having four tanks for the reception of raw solids, we therefore have about six volumes of digesting matter for every volume of raw sludge. Since the digesting sludge contains a considerably higher percentage of solids than the incoming raw sludge, the ratio of solids by weight in the tank is consequently greater than the above volumetric ratio.

Time Required.—Various laboratory tests by others indicate that at about 85° F. sewage solids in the presence of properly seeded sludge will proceed to substantial completion of digestion in three weeks. We have no accurate method for determining the average length of our digestion period because we take off supernatant liquor from at least one tank and transfer digested solids from the bottom of a digestion tank into an open storage tank each day, without making a solids balance.

Coefficient of Heat Transfer.—The heating of separate digestion tanks presents some interesting problems, as regards the amount of heat required and the position of the heating elements. The most common method of heating is to circulate hot water within wrought iron coils submerged in the sludge. Digesting sludge does not absorb heat from iron surfaces nearly so readily as does water, because the sludge is viscous and tends to adhere to the pipe, creating a layer of insulation through which the heat does not readily pass. Also because of its viscosity, the convection currents set up within the sludge by the heating coils are not as rapid as in clear water and there is not the strong sweeping action necessary to good heat transfer. I ran a series of carefully controlled experiments in tanks each having approximately 500 square feet of heating surface. With coils submerged in sludge of 12 per cent solids content, the coefficient of heat transfer was found to be about 11 B.t.u. per square foot of heating surface per hour per 1° F. temperature differential. With the same coils submerged in very thin sludge approximating strong supernatant liquor, I found the heat transfer to be 39 B.t.u. The difference is good indication of the effect of sludge density upon heating. In both cases the pipes were new and clean.

Circulating Water Temperature.—We formerly circulated the water at a temperature of around 170° F. After the coils had been in service for two years we found the outer surfaces incrusted to a depth of an eighth of an inch with a hard, brittle substance which probably cut down the efficiency of heat transfer to a marked degree. For the past two years we have kept the temperature below 155° F. We recently had occasion to examine the coils, and found no evidence of incrustation. Ordinarily the heating water is recirculated within a closed system of pipes and there is little or no danger that pipes will become seriously incrusted on the inner surfaces. However, if the water supply is quite hard, and if considerable quantities of make-up water are used, the coils may become caked inside with a hard scale. In such cases the water temperature should be kept below 150° F.

Position of Heating Coils.—Designers formerly placed the heating coils against the walls because they provided a convenient means of support. If they are so placed the convection currents cannot sweep around them. More recent tanks have been built with coils supported at a distance of several feet away from the walls. The coils in our tanks are arranged in hexagonal form, with the angles about two feet from the walls.

In general, the coils should be placed in the region of the most actively digesting materials--wherever that may be. In a tank which is behaving well, the concentration of solids below the supernatant liquid becomes progressively greater as depth increases, with the more fully digested material nearest the bottom. Obviously the coils should be above this material and below the supernatant liquid. Since both levels are variable, one should distribute the coils in vertical depth, having the bottom one perhaps three or four feet above the floor and the top coil somewhat above mid-height. Some have contended that a part of the coils should be placed near the very top of the tank so as to prevent scum formation at the surface due to chilling, but our experience with the floating covers shows that the heat is quite uniformly distributed from top to bottom. In one test we found no variation exceeding 1° F. throughout 3-foot intervals in a sludge depth of 27 feet. At the time of the test, the liquid in contact with the cover had a solids content of 0.36 per cent. Below the supernatant liquor line the density varied reasonably uniformly with depth from 5.03 per cent to 12.4 per cent solids. The temperature was uniform at 92° F. throughout the tank.

Heat Loss from Tanks.—Last winter we ran a test to determine the relation between the amount of heat put into the recirculating coils, and the heat required to raise the sludge to digestion tank temperature. The record shows that between November 4, 1933, and February 14, 1934, we put 1,212 million B.t.u. into the circulation water. During the same period, only 685 million B.t.u. were required to raise the temperature of the sludge to the temperature of the digestors. This indicates that during the winter only 56.5 per cent of the heat was usefully employed, and points the way to the necessity for designing for heat conservation. Our tanks are of concrete, the cone is 12 feet into natural ground, the walls are protected with an earth embankment 18 feet high, and the tops are covered with steel domes. It costs us nothing to heat the tanks at Springfield, because we use the heat salvaged from the water jacket and from the exhaust pipe of our gas engine. However, in most places heat costs money and a little more money spent upon insulation may yield good returns during operation.

Foaming.—Foaming creates a very bad situation at some plants, although we have had little trouble from this source. Our tanks are now provided with gravity outlets into the open storage tanks, and whenever we see evidences of foaming, we drain away the top material. In the open storage tanks the foamy scum quickly loses its identity and is eventually fully digested. Foaming is an indication that digestion is not proceeding correctly, which may be due to one of several causes. We usually find when foaming occurs that the active digestion time is too short, too much of the tank volume being occupied by sludge which is already digested. The foaming usually stops quickly after we remove some of the heavier solids from the cone. Some operators resort to the use of lime to raise the pH at least to neutrality, but we have never done so except for a few times just to see what would happen. Our experience with the use of lime has been quite indifferent and inconclusive. An examination of our records, given later in the paper, will show that for almost two years the reaction has uniformly been on the alkaline side, indicating that the tanks would not have been aided by the addition of lime.

Formation of Scum.—The formation of scum has caused trouble at plants and formerly gave us something to worry about. After the floating covers had been in service for perhaps a year, we opened one of the gas domes to examine the material nearest the metal skin. It consisted of a black, heavy, stringy mass of leaves, sticks, rags, paper, etc., matted together and slimed with oil and grease. We had some difficulty in trying to force the head of a rake through it, and our fear was that we would have to remove it by hand. Instead, we shut the tank cover and left it. Some time later we reopened the tank and found that most of the scum had digested. At least there was much less than formerly. So it has been for five years, alternately coming and going. Scum has at times been so heavy and dry upon the surface of our open storage tanks that one might safely walk upon it, but after a few weeks the tank surface is entirely free of scum. We have always noted that when it begins to digest, the tank becomes very much agitated and gas ebullition is violent, indicating active digestion.

Some of our scum troubles have been alleviated by the operation of a grease-removal basin installed ahead of the settling tanks. From the grease tank, we skim grease, oils, and all manner of light-weight substances which are difficult to digest. Of course we lose some gas by keeping the grease out of the digestors, but I would rather lose it than try to separate the methane-forming material from the other matter. Other plants have digested this same material without apparent difficulty and we could probably do so if we put it into the tanks regularly and in small amounts. We may try it, but our present disposition is to leave well enough alone.

Supernatant Liquor.—The disposal of supernatant liquor from separate sludge digestion tanks presents the most vexing problem, particularly at activated sludge plants. When the tanks are behaving nicely, there is a clear separation of liquid from solid, and the supernatant might well be wasted directly in the plant outfall, although the propriety of doing this depends largely upon the size and conditions of the effluent stream. When the supernatant is heavy and apparently not fully digested, we send it back to the incoming sewage, and the solids are settled out in the primary tanks. When the liquor is high in solids, the primary tank effluent may contain more solids than are present in the raw sewage. However, with adequate secondary treatment our overall plant efficiency is bettered by sending the supernatant liquid to the primary tanks instead of directly to the plant outfall sewer, even though such practice puts a heavy overload upon the primary tanks. It is probable that supernatant liquor troubles are more acute at activated sludge plants because the mixture of primary and activated sludge does not digest as well nor as rapidly as does primary sludge alone.

At plants so situated that a large open lagoon causes no nuisance, lagooning the supernatant liquor offers a ready and cheap means of disposal, particularly if used only during times when the digestion tanks are not in first class condition. We have been using a lagoon for such purposes for several years and have found it a helpful adjunct to the plant. Indeed, there are localities so situated that all the sludge, both primary and secondary, may be lagooned, and under certain conditions I think it a very reasonable means of disposal.

Stage Digestion.—It is undoubtedly true that digestion in two or more stages results in better supernatant liquor. In the first stage, the fresh solids are intimately mixed with partially digested sludge. The period of solids retention, in the more recently designed tanks, is relatively short, and no attempt is made to obtain supernatant liquor—in fact the solids are agitated so thoroughly that separation of liquid from solid would be impossible. From the first stage, the solids pass into larger tanks wherein digestion proceeds more quietly and is carried to the desired degree of completion. In some instances, provision is made for even a third step. In such cases, the first and second tanks are usually covered with gas domes, while the third is almost invariably open, although such practice is not inherently necessary.

Stirring and Mixing.—Authorities differ widely concerning the degree of stirring and mixing required in a digestion tank, some advocating a violent agitation, particularly in the first unit of stage digestion, while others hold that no mechanical agitation is necessary. At the Springfield plant, the solids enter the top of the tank near the center, and are partially dispersed by the velocity effect at entrance. I believe that the convection currents set up by the heat coils cause a very considerable movement throughout the whole tank and that gas bubbles, continually arising from the solids, likewise exert a strong stirring movement. We recirculate some sludge from the bottom into the top, but rarely in excess of 15,000 gallons a day. The temperature distribution throughout the tank is a fair measure of the movement of the liquid, and in our case it appears that the combination of entrance velocity, gas bubbles, convection currents, and a minimum of artificial recirculation, results in a well seeded tank.

Analytical Data.—It is always interesting to examine the operating results of a plant, particularly when some one connected with that plant describes certain parts of the routine. Table II, given below, is taken from the annual report of our plant for 1933, the analyses for which were made by C. C. Larson, Chemist of the Springfield Sanitary District.

The table shows a reasonably high percentage of fixed and total solids in the digested sludge. If we had more drying beds, we could unquestionably obtain a higher average for total solids. The reason for this is that whenever a drying bed is emptied, we have to put more sludge onto it, without waiting until we can get heavier sludge from the tanks. As a result, we often have to fill a bed with material containing perhaps only 4 or 5 per cent total solids content, thus bringing down the general average. We have drawn sludge with upwards of 16 per cent solids, but it flows so slowly down the draw-off channels that we do not make any effort to obtain such densities.

Drying on Sand Beds.—Probably the main purpose of a digestion tank is to transform sewage solids so that they will drain and dry quickly and inodorously upon drying beds. Unfortunately I know of no simple test by means of which an operator may know when the sludge is in proper condition for sand bed drying. It is undoubtedly true that one measure of "good sludge" is the relation between fixed and volatile solids. Generally speaking, digested sludge will dry readily if the fixed solids approach or exceed 50 per cent by weight. Experience shows also that properly digested sludge is jet black in color and gives

TABLE II.—*Springfield Sewage Treatment Plant*
Digested Sludge Data

Month 1933	Drying Beds Filled	Gallons Sludge Drawn to Drying Beds	Per Cent Solids		Tons of Dry Sludge Produced (50% H_2O)	pH	Tank Temperature
			Total	Fixed			
January	5	123,400	4.34%	47.7%	45.0	6.6	71°
February	5	89,000	7.29	51.2	59.4	6.9	75
March	5	105,000	6.55	53.2	58.8	6.9	81
April	4	74,200	7.82	53.9	48.4	7.0	80
May	2	32,900	7.91	53.7	22.2	6.9	80
June	12	164,600	11.24	62.8	171.3	7.1	85
July	17	232,400	11.63	65.2	248.0	7.2	94
August	17	257,000	8.71	62.5	183.6	7.1	93
September	14	235,500	8.19	61.4	163.6	7.1	94
October	8	125,000	7.63	59.7	81.0	7.2	95
November	7	92,200	7.55	58.3	58.9	7.2	98
December	4	68,300	6.78	51.9	37.8	7.4	99
Total	98	1,599,500	—	—	1,178.00	—	—
Average		133,300	8.40*	56.8*	98.2	7.1	87
1930 Total	55	1,188,100	—	—	936	—	—
Ave.		99,000	9.6*	59.3*	78	7.0	
1931 Total	73	1,260,310	—	—	1,025	—	—
Ave.		105,026	9.5*	59.5*	86	7.0	82°
1932 Total	112	1,712,200	—	—	1,475	—	—
Ave.		155,654	9.2*	60.6*	134	7.0	79°

* Weighted average.

The above figures do not represent the total amount of digested sludge produced during 1933 because some sludge was drawn to a lagoon. Furthermore during a portion of the year the supernatant liquor from the digestors was also discharged into the lagoon and upon drying produced considerable sludge.

off an odor resembling coal tar. In spite of any test to the contrary, however, the final answer is given upon the sand beds. We have been very fortunate during the past five years, in being able to produce sludge which dries readily. The surfaces of the beds crack open, leaving irregular pieces like islands, four or five inches in greatest dimension. It is obvious that when the cracks are more numerous and deeper, more sludge surface is exposed to the action of the sun and wind.

The time of drying is important, but data from various plants are not comparable because some operators remove sludge from the drying beds while it is soggy and wet, while others, who have ample drying space available, can wait until the sludge is quite dry.

Our experience indicates that increased digestion temperatures may affect the drying time adversely. No conclusive data are available, but our records tend to show that the sludge must remain longer upon the beds when it comes from tanks kept at 95° F. than when it comes from tanks heated only to 80° F .

Gas Collection.—Accompanying the digestion of sludge, gas is evolved in amounts approximating and possibly exceeding the weight of volatile matter digested. The quality of gas and the chemical constituents thereof vary with the variation of many factors, including the temperature of digestion, the pH of the sludge, the time in the tanks, the amount and characteristics of the raw sludge, and the degree of digestion. In general, gas collected from separate sludge digestion tanks will have net or lower heating values ranging from 550 up to 620 B.t.u. per cu. ft. The gross or higher heating value is approximately 10 per cent above the lower. At most plants, the gas is used for heating the tanks and buildings, or for burning screenings. In some instances it is wasted, but the financial value of the gas will generally warrant its collection and use.

Most plant operators report the amount of gas collected in cubic feet per capita per day, since this is a convenient basis of comparison. Perhaps it would be better to record gas quantities in terms of equivalent population. However, since the sewage at Springfield is regarded as domestic, our results would be the same in either case. The average amount of gas used by months since January, 1933, and also the temperature and pH of the tanks are shown in Table III.

Unfortunately we do not have the means whereby we can measure all the gas produced. The gas volumes given in Table III represent only that portion actually used by the gas engine. We know that large quantities escape from beneath the holder when it is full, and while we try to avoid wasting gas, we cannot at all times use the entire quantity generated. Because we do not know how much gas comes from the tanks, we are unable to make safe generalizations concerning the effect of temperature and pH upon production.

Gas Power Development.—We use gas at Springfield to run an engine, deriving therefrom a very substantial saving in power. The engine was started Jan. 2, 1933. The entire cost of engine, heat salvage equipment, one new floating cover, and the 23,000 cubic foot gas holder, was $15,728. The engine has a maximum capacity of 180 horsepower, and is direct-connected to a Connersville air blower, tests upon which show that when motor driven, it requires 525 K.W.H. to compress 1.0 million cubic feet of air under our plant conditions. During 21 months

TABLE III.—*Springfield Sewage Treatment Plant*
Gas Used by Gas Engine

Month 1933-34	Cu. Ft. of Gas per Day	Cu. Ft. per Capita per Day	Average Temperature of Digestors	pH of Digestors
Jan.	29,253	0.42	71° F.	6.6
Feb.	39,711	0.57	75	6.9
March	44,745	0.64	81	6.9
April	30,983	0.44	80	7.0
May	27,340	0.39	80	6.9
June	33,497	0.48	85	7.1
July	49,200	0.70	94	7.2
August	36,153	0.52	93	7.1
Sept.	38,617	0.55	94	7.1
Oct.	50,459	0.72	95	7.2
Nov.	53,593	0.77	98	7.2
Dec.	53,610	0.77	99	7.4
Jan.	61,232	0.87	97	7.3
Feb.	51,689	0.74	93	7.3
March	59,697	0.86	91	7.1
April	60,203	0.86	97	7.3
May	59,148	0.84	97	7.3
June	56,696	0.81	96	7.2
July	53,597	0.77	93	7.3
August	52,752	0.75	97	7.1

of operation the gas engine driven blower has compressed 2,401 million cubic feet of air. The savings have therefore been equal to the cost of 1,260,500 K.W.H. of electricity, an average of 60,000 K.W.H. per month. During the nine months of 1934, the savings have been more than in the twelve months of 1933. From January 1 until Sept. 30, 1934, the engine has saved 724,000 K.W.H., or an average of 80,500 K.W.H. per month, even though we are still unable to utilize all of the gas produced. The saving of 80,500 K.W.H. each month with a capital expenditure of $15,728 looks like a good investment, irrespective of the unit price for electric current. During the past 21 months, our operating expenses have been remarkably low, averaging less than $100 per month for interest, depreciation, oil, repairs, and materials and labor of maintenance. So far as the engine alone is concerned, it has paid for itself two times in the one and three-quarter years. In fact, the gas power production has proved so satisfactory that the Springfield Sanitary District has purchased a second engine of 150 horsepower capacity, which will bring our total installed capacity to 330 horsepower. The new engine will drive a Connersville blower and also an electric generator to produce the current for the small auxiliary motors and lighting requirements of the plant. Normally there will not be enough gas available to run both engines for 24 hours a day, but the supply is more than sufficient to justify the purchase of the second engine to use that portion of the supply which is now wasted.

Digestion versus Filtration.—As an efficient and economical method of disposal, separate sludge digestion is now being challenged by filtration of raw sludge and it may be that by the time we learn the intricacies of digestion, the process will be superseded. In my opinion, however, the possibilities of power production from the gas evolved will tend to lengthen its life tenure at many plants, particularly those at which large quantities of power are required. As an example of the value of sludge gas, the Springfield record may be of interest. Accounting for all construction and equipment required to handle the sludge from the walls of the primary tank, to and including the sand drying beds, and accounting for the gas collection and utilization equipment, our installed costs for sludge handling total $99,918. Charging this at the rate of 8 per cent, gives an annual fixed charge of about $8,000. To this must be added the cost of labor, maintenance and repair parts, power, proportionate supervision and incidental expense, amounting to about $4,225, bringing the total charge to $12,225 per annum. As a partial offset to this, we will in 1934 save about 945,000 K.W.H. of electric current by means of our power development. At 1.0c per K.W.H. this will return us $9,450, leaving a charge of $2,775 as the net annual cost of collecting, digesting, drying and disposing of sludge. After our second gas engine is in operation we expect to save even a greater sum annually.

So far as concerns a situation closely approximating conditions at Springfield, Illinois, I seriously doubt that a plant for the filtration and drying of sludge can be built and operated to handle and dispose of raw primary and activated sludge at a net annual charge less than that indicated above. It is a self evident fact that if we paid more than 1c per K.W.H. for current, the annual savings credited to the engine would increase proportionately, and it does not require much figuring to show that with materially higher electric rates, the digestion process would prove self sustaining. On the other hand, in some of the larger cities, the cost balances between filtration of raw sludge and digestion are not seriously against filtration, especially if land for sand drying beds is prohibitively high. However this statement is based solely upon assumed cost estimates and not upon actual installations.

Summing up, I would say that separate digestion, properly attended and controlled, offers at present a very satisfactory method of disposing of sewage sludge, and in my opinion much work must be done on the development of competitive processes before digestion is superseded by filtration of raw sludge.

THE KITCHENER SEWAGE TREATMENT PLANT ITS DESIGN, CONSTRUCTION AND OPERATION *

By William Storrie

Of Gore, Nasmith & Storrie, Consulting Engineers, Toronto

Kitchener is the most highly industrialized city in Ontario, if not in Canada. The first evidence of any pioneer settlement took place on or about 1799. A memorial tower was built on the banks of the Grand River opposite Doon in 1928 to commemorate the establishment of the city. The settlement was named Berlin in 1830; previous to that time it had been known as Sand Hills. It was incorporated as a village in 1854, a town in 1871 and a city in 1912 changing its name from Berlin to Kitchener in 1916. The population at the end of 1933 was estimated to be 31,328. The area of the city is 3,477 acres which gives an average density of population of 9 persons per acre.

This inland city is three miles from the Grand River and is situated on a small stream called Schneider's Creek, which has a flow of 3 million gallons a day. This creek is the only water available for dilution of sewage and sewage plant effluents. The water supply of the city is derived from deep wells and the average water consumption is around 68 Imp. gallons per capita per day. A large quantity of water in addition is used for industrial purposes, some of which is derived from privately owned wells. The sewerage system is of the separate type.

There are a number of large industries in Kitchener, many of which discharge large volumes of trade wastes into the sewers. Among these are three tanneries, a dye works, a felt works, a glue factory, three tire and rubber factories and two abattoirs. The industrial wastes from these works make the Kitchener sewage the strongest known in Canada, with a total solid content of from 2,000 to 3,200 p.p.m., and suspended solids of from 700 to 1,200 p.p.m., depending upon business conditions.

On account of the great strength of Kitchener sewage and the small amount of dilution existing previous to 1931 it has always been necessary for the city to treat its sewage. As a consequence the history of the city is closely associated with the history of the development of sewage treatment, since practically every type of sewage treatment plant has been tried out. The first Kitchener sewage installation was land treatment on a sewage farm, upon which crops were grown. The land was unsuitable for the purpose and the sewage from it was allowed to flow into Schneider's Creek. Later a Cameron septic tank was added when septic tanks came to the fore. The septic tank soon filled up and proved to be of little value in solving Kitchener's sewage problem or protecting the creek.

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* Presented before the First Annual Convention of the Canadian Institute on Sewage and Sanitation, Toronto, Oct. 18, 1934.

In consequence of the nuisance created along the creek, actions were brought against the city and damages awarded to farmers through whose properties the creek meandered and an injunction was also granted which necessitated the construction of a new sewage treatment plant. On the advice of Dr. Amyot, of the Provincial Health Department, who in 1903 had carried on work on Kitchener sewage with experimental trickling filters and contact beds, the well tested system of intermittent sand filtration was adopted and 21 acres of underdrained sand beds were put into use. This system proved successful but as there was no additional suitable sandy area available for extension purposes the beds could not be enlarged as the city grew in population. Consequently in time these beds were unable to take care of all the sewage.

Later on, in an attempt to alleviate the situation, an Imhoff tank and trickling filter, designed to treat 400,000 gallons of sewage per day, were added to the sewage treatment plant, which then consisted of the old septic tank which had been converted into a primary settling tank; shallow sludge lagoons for drying the sludge from the settling tank; 21 acres of sand filtration beds; an Imhoff tank; trickling filters and a humus tank.

By 1928 the system had become so overloaded that local nuisances again developed, new lawsuits were threatened and the city was faced with the alternative of further additions to the sewage treatment plant or building an entirely new plant. Experimental work on a small scale carried out by officials of the Ontario Department of Health had demonstrated that the Kitchener sewage could be treated successfully by the activated sludge process, provided that not more than two parts of trade wastes were present to one part of domestic sewage. A small activated sludge plant to take care of part of Kitchener's sewage had meanwhile been put into operation at the Spring Creek Plant and was working successfully on a weaker sewage.

This was the situation when the firm of Gore, Nasmith & Storrie was retained by the city to prepare a report of the problem and as a result of their report to prepare plans for a new sewage treatment plant on the Grand River at Doon, three miles from Kitchener. Following representations made by the city, the Provincial Department of Health agreed that for the time being it would not insist upon complete sewage treatment but would allow the city to build that section of the plant necessary for the removal of suspended solids, complete treatment depending eventually upon whether or not a nuisance was created in the Grand River.

A site of 110 acres was selected near Doon in the Grand River Valley. The work of constructing the new plant was begun in 1930 and the following year the plant was put into operation. Out of a total population of 31,328 the population tributary to the Doon Plant is estimated to be 25,000.

The Kitchener Sewage Treatment Plant at Doon was designed solely for the purpose of removing suspended solids from the sewage, digesting such solids and dewatering the digested sludge. The plant was designed for 4 million gallons daily dry weather flow and capable of treating, over a short period, at a rate of 8 million gallons daily. Tests indicated the suspended solids in the sewage to be about 750 p.p.m. or 30,000 pounds dry weight per day at the 4 million gallons daily rate. Compared with a normal sewage such as that of North Toronto the amount of suspended solids is equivalent to that from the domestic sewage of a population of over 200,000 persons.

The plant (Fig. 1) consists of a mechanically cleaned bar screen to remove very coarse solids; a detritor to remove grit and other heavy settleable solids; two primary settling tanks equipped with scrapers; two heated digestion tanks equipped with stirring mechanism; and glass-covered sludge drying beds for drying the digested sludge. The highly colored effluent from the primary settling tanks is discharged into the Grand River. The overflow from the digestion tanks is re-

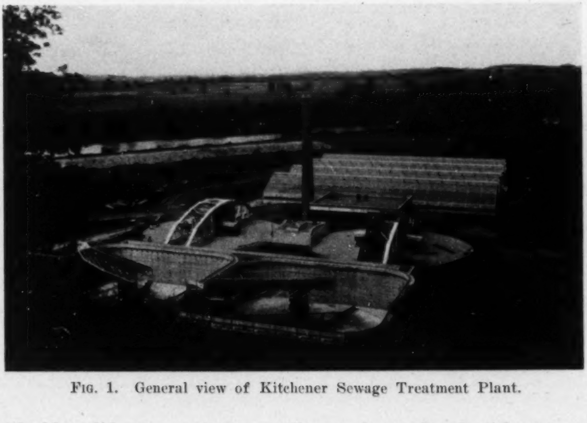

FIG. 1. General view of Kitchener Sewage Treatment Plant.

turned to the primary settling tanks for the removal of any settleable solids present. The gas produced from the heated digestion tanks is burned in two gas-fired boilers and the heat therefrom utilized to heat the digestion tanks, the drying beds and the buildings.

Construction.—The sewage is conveyed to the site through a 48-in. diameter reinforced concrete trunk sewer. This sewer is constructed with concrete pipe in the open and the tunnel portion, about 1,016 feet in length, is of reinforced concrete built in place with a fireclay lined invert. The sewage enters the plant at the screen and grit house through an orifice designed in conjunction with an overflow weir to limit the total flow into the plant to about 8 million gallons daily. A gate is provided on the orifice to reduce the amount of sewage treated or to bypass the plant entirely. The sewage passes first of all through a mechanically cleaned bar screen, electrically operated, and thence into a compartment in which is placed a detritor collecting mechanism of the traction type, electrically operated. The solid matter retained on the mechanically operated screen and the collecting portion of the combined detritor is passed through chutes into industrial cars situated in a floor below and taken to the spoil bank. Both the screen and detritor are capable of handling 8 million gallons of raw sewage per day.

The sewage then passes into two primary settling tanks, each 60 feet square with rounded corners and a depth at the walls of 13 ft.–6 in. and at the centre of 15 ft.–7 in. The collecting sump at the centre is 3 ft.–3 in. lower than the floor level at the centre of the tank. The clarifier mechanism is of the traction type and electrically operated. The retention period in these tanks is approximately 3 hours at 4 million gallons daily rate of flow and the effluent flows through a series of port holes and over a weir thence to the outfall sewer, for the most part 48 inches in diameter, which discharges the effluent without further treatment into the Grand River.

The settled sludge is carried by gravity through two 8-in. cast iron pipes into the digestion tank. Hydraulic valves automatically controlled by electric motor-operated timing relays are installed on these pipes to permit of the periodic transfer of sludge. By means of these relays the intervals at which the valves are operated as well as the time the valves remain open are adjustable and may be set as desired.

These valves are also arranged for operation from floats on the digestion tank water levels to prevent the lowering of the sludge below the gas seals.

These digestion tanks are two in number, each 65 feet in diameter and 22 feet deep at the walls. The tanks are fitted with rotating stirring mechanisms, electrically operated, with a speed of 3 revolutions per hour. The tanks are covered over with a gas-tight concrete roof, no freeboard being allowed. The maximum gas pressure is equivalent to 21 inches of water. Two gas collectors are provided for each tank, made of steel plate 2 ft.–2 in. by 6 ft. 5/16 in. thick. Each tank is provided with a suitable gas-tight concrete manhole properly sealed.

The cylindrical walls are reinforced to resist the full internal pressures by ring tension and are separated from the floors by expansion joints to reduce as far as possible the cantilever moments.

The reinforced concrete roof slabs are carried on structural steel beams encased in concrete and suspended from steel trusses which also carry the rotating stirring mechanisms. The roofs are well insulated to reduce the heat losses.

After a detention period averaging nearly two months the sludge is withdrawn to the sludge drying beds.

A combined heating plant and office building contains both coal and gas fired boilers, coal storage, pumps, meters, wash rooms, lavatories, general office, laboratory, store room and brick chimney.

The sludge drying beds are of the greenhouse type, four in number, each 149 ft.–5 in. in length by 40 ft. in width. (Fig. 2.) They are of sectional iron-frame construction erected on cencrete foundation walls, with genuine wrought-iron posts spaced about 8 feet apart placed on the sides and ends of the glass-overs and embedded in the concrete walls for a depth of 2 ft.–6 inches. A system of vitrified tile underdrains is laid

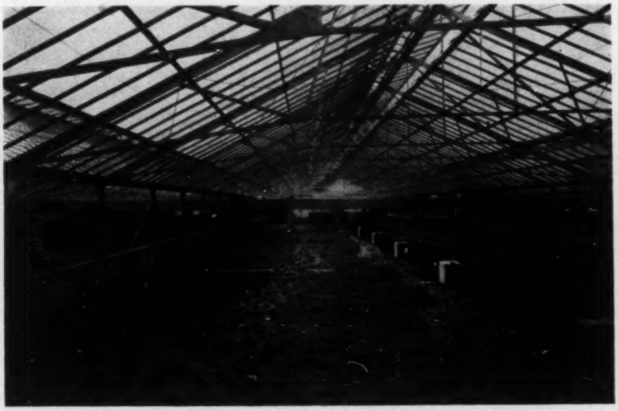

FIG. 2. Glass-covered sludge drying beds.

down in each bed. The drainage bed consists of coarse gravel from 1 in. to 1½ in. in size to a depth of 3 inches and surrounding the underdrainage system of tile pipes, then medium gravel from ½ in. to 1 in. to a depth of 3 inches, then fine gravel from ¼ in. to ½ in. to a depth of 3 inches and then coarse sand up to ¼ in. in diameter to a depth of 3 inches. On top of this gravel is laid a bed of sand to a depth of 6 inches. Industrial tracks have been laid on a framework of timber throughout each bed (Fig. 3) to carry the cars for conveying the dried sludge. These cars are hauled by a gasoline-driven locomotive.

The materials used in the construction of the plant followed the usual practice for work of this type. Reinforcing rods were rolled from standard T-rails and Portland cement was used throughout. Three grades of coarse aggregate and two classes of concrete were used, that of Class A having a minimum compressive strength of 3,000 pounds per square inch and Class B of 1,500 pounds per square inch. Ninety-five per cent of the total concrete placed was of Class A. Regular tests were made of the concrete work to determine whether the concrete as produced by the proportions given was of the specified quality. All concrete was mixed by machine. The centering and form work followed the usual practice. Expansion joints were placed wherever required in the concrete floors, walls and roofs.

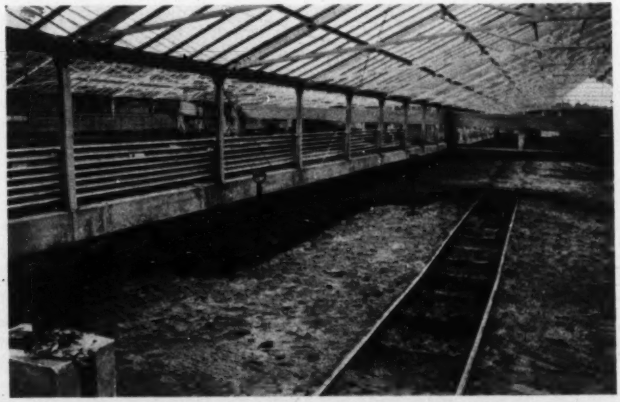

FIG. 3. Sludge on drying beds after eight days.

Operation.—The raw sewage coming to the treatment plant amounts to about 3.4 million Imp. gallons a day, of which a large proportion is industrial wastes. It contains spent tanning liquors, spent lime, large quantities of hair from both tanneries and felt works, abattoir wastes, spent dyes and other materials difficult to treat, such as mash from home brewing and grapes from wine making in the autumn season.

About 480 pounds dry weight of rags and other coarse material are removed daily by the automatically cleaned coarse rack. The detritor removes about 735 pounds dry weight daily of grit and other heavy material. The primary settling tanks remove 51 per cent of the suspended solids in the sewage after it has passed through the detritor.

The production of gas in the digestion tanks amounts to 3,000 cu. ft. per hour or 72,000 cu. ft. per day. On a population basis of 24,000 this amounts to a gas production of 3 cu. ft. per person daily. This gas has a heating value of over 600 B.t.u. per cubic foot. It is sufficient for all the heating requirements except during very cold weather.

The overall removal of suspended solids by the plant during a nine-day official test by the Provincial Department of Health of Ontario in the summer of 1932 was 55 per cent or about 14,000 pounds dry weight per day. A further series of tests taken during nine days in September, 1934, confirms these results. During this same test, analyses of the river water below the plant were made on three different days to determine the oxygen saturation. The minimum average oxygen saturation was 72 per cent at Blair, about 3 miles below the sewage plant outfall. Below this point the oxygen saturation rapidly increased to 100 per cent. These analyses indicate that the flow in the river is adequate to prevent putrefaction at the present time at any point in the stream, though the color of the river water, due to tannery and dye wastes, does not disappear for several miles down stream.

A good deal of difficulty was experienced during the early months of operation from the enormous quantities of hair which came to the plant from the tanneries and felt works. During the period of filling the digestion tanks with fresh sludge solids, which occupied several months, all of the hair removed from the sewage accumulated in the digestion tanks, since no digested sludge was being withdrawn. As fermentation took place the gas generated carried the hair to the surface of the closed digestion tanks where it formed a dense mat two or more feet in depth. This hair mat was so tough and the friction of moving it so great that it stopped the mechanical stirring apparatus. It was found by the operators that if the covers of the two manholes on either side of the top of each digestion tank were taken off and the hair which had accumulated in the manholes removed by hand the load on the stirring mechanism would be sufficiently reduced as to allow it to operate for a time. Accordingly, for several months this hair accumulation was removed from the manholes several times a week, with the result that conditions gradually improved, until in July, 1932, one of the tanks was operating without the necessity of removing any hair through the manholes.

At this time a meeting of the managers of the abattoirs, tanneries and felt factory, together with the operators, members of the sewer committee and the consulting engineers was held. The situation was explained and the tanks examined by the industrial works manager and their cooperation asked for in making a reasonable attempt to keep their several plant catch basins in order and to prevent excessive quantities of this objectionable hair coming to the treatment plant. Whether this was responsible for the result or not cannot be determined but it was significant that immediately thereafter smaller quantities of hair appeared to be coming to the plant and by October the second tank was also operating normally and little or no hair has had to be removed from the manholes in either tank to date. That plenty of hair is still present may be readily seen by examining the dried sludge, which is thoroughly matted with hair. We are of the opinion that when the tanks began digesting sludge satisfactorily, and when the heavy accumulation of hair which had gathered in the tanks during the preliminary filling period had been removed, the day-by-day quantity of hair which came was readily handled and removed with the digested sludge at the same rate that it enters the digestion tanks.

Sludge Disposal.—As previously indicated about 5,000 cubic yards of dry sludge is produced from the plant yearly. During the first 2 years of the operation of the plant practically none of the sludge was taken away for fertilizing purposes. About two acres of land adjoining the plant were set aside to show the market gardeners in the vicinity of Kitchener what could be accomplished by using this sludge. All kinds and varieties of flowers and vegetables were grown with excellent results thus indicating in a very practical way the fertilizing value of the sludge. It is pleasing to note that during last year the sludge was hauled away from the plant at a rate faster than it was produced. The trucksters are given the sludge but they must load their trucks.

The drainage area of the Grand River at the Doon Sewage Treatment Plant is 1,074 square miles. The maximum flow of 23,000 cu. ft. per sec. occurred March 18th, 1919, and the minimum flow of 40 c.f.s. July 1st, 1925. The maximum annual mean flow occurred in 1929 amounting to 1,400 and the minimum annual mean flow occurred in 1931, amounting to 380 c.f.s. The average annual mean flow over a period of 19 years has been 900 c.f.s. The average daily discharge from the sewage treatment plant during 1933 was 3,391,000 gallons or 6.3 c.f.s. It will thus be seen that under almost all conditions the dilution in the river is large and is such that it is not considered necessary to put in aeration tanks, at least for some time to come. It is realized that the solids content of the sewage is excessive. The time will come when complete treatment will be required but nothing has so far developed that would indicate the necessity for it and we believe it will be years before it will be necessary.

The site is subject to flooding during the spring freshets but only in years when the flow is abnormally high. To safeguard the structures a protecting dike was constructed along the south bank of the Grand River. This dike is 800 ft. in length with a maximum height of 16 feet. It is flat on top for a width of 8 ft. with slopes of 2 to 1 on either side. The dike was constructed from excavated material taken from the site and faced with stones on the river side taken from the river bed. On the sloping face next to the water poplar trees have been planted with the object of still further protecting the dike from erosion and this appears to be quite successful.

The total cost of the completed works was approximately $330,000.

The design of the works, the supervision of construction and the operation for a period of one year after placing the plant in service were carried out by Gore, Nasmith & Storrie, Consulting Engineers, Toronto. Stanley Shupe was city engineer and A. D. Huether acted as resident engineer throughout the construction of the plant. The main contract was carried out by the Dunker Construction Company, Limited, Kitchener, and most of the sewage equipment was provided by the Dorr Company of Canada, Limited.

The plant has been in operation for fully three years under the supervision of Mr. Shupe with Ephriam Ernst as Superintendent, both of whom deserve great credit for the excellent results being obtained.

REMOVAL OF HYDROGEN SULPHIDE IN SEWAGE BY AERATION

By W. S. Mahlie

Chemist-in-Charge, Sewage Treatment Works, Ft. Worth, Texas

The sewage treatment plant at Fort Worth was designed to treat 16 m.g.d. of a very strong sewage composed of an initially strong domestic sewage mixed with previously screened and settled packinghouse wastes.

The plant consists of grit chambers, Imhoff tanks used as primary settling tanks, pre-aeration tanks, secondary settling tanks, sprinkling filters and final settling tanks. Sludge is digested separately in three Dorr digesters 75 feet in diameter, equipped for gas utilization. A complete description of the plant is found in *Proceedings* of the American Society of Civil Engineers, part 1, page 1405, August, 1929.

Ever since the plant was put in operation (October, 1929) we have had considerable difficulty with odors. In spite of this odor nuisance the plant has consistently produced a good effluent.

Studies extending over a considerable period of time have shown that there is a marked increase in the hydrogen sulphide content in passing through the Imhoff tanks, a decrease in passing through the aeration tanks, an increase in passing through the secondary settling tanks, and practically complete elimination in passing through the sprinkling filters. The average for a year, October 1, 1933 to October 1, 1934, has shown as follows:

Raw sewage	4.5	p.p.m	H_2S
Imhoff tank effluent	8.9	“	“
Aeration tank effluent	2.4	“	“
Secondary tank effluent	3.7	“	“
Sprinkling filter effluent	0.05	“	“
Final clarifier effluent	0.05	“	“

The increase in H_2S content in passing through the Imhoff tanks can be explained by the fact that supernatant overflow liquor from the digester (containing about 50 to 60 p.p.m. H_2S), and excess secondary tank sludge containing about 8 p.p.m. H_2S) is added to the raw sewage just before entering the Imhoff tanks. The volume of these added liquors is not enough to account for the increases found, but some digestion occurs in the tanks, as the sludge cannot be completely removed, and the digester overflow liquor produces an excellent seeding material for H_2S producing bacteria. The sludge from the secondary settling tanks becomes septic very quickly, even more rapidly than the raw sewage sludge, and gives rise to increased H_2S in the secondary tank effluent.

A series of tests were conducted during January and February, 1934, to observe the rate at which H_2S was removed by aeration process.

The aeration tank consists of a five-battery unit: four of these batteries being used for aerating the mixed liquor, and the other for reaeration of return sludge. Each battery consists of five channels, 145 feet long, 10 feet wide and 10 feet deep, commonly spoken of as the Indianapolis type of design.

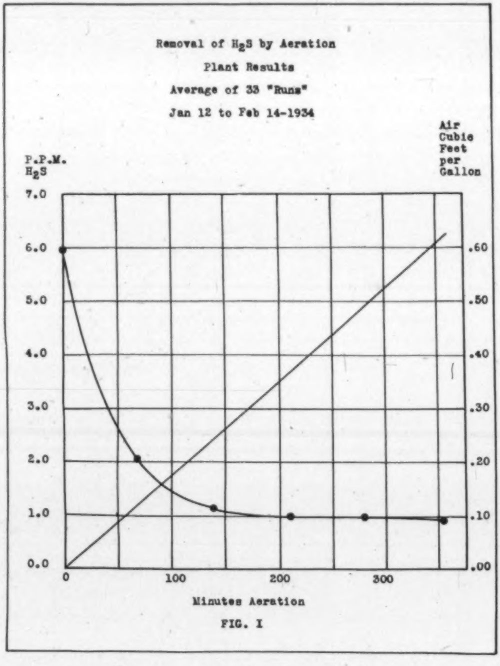

FIG. I

Sewage enters one end of the first channel, flows to the far end and enters a second channel flowing in the opposite direction, and so on into the succeeding channels. Samples were taken at the influent end of each channel and at the effluent end of the last channel.

H_2S was determined by the method described in *This Journal,* Vol. VI, page 576, May, 1934. The rate of sewage flow, and the rate of air application was recorded at the time the samples were taken and the flowing-through time for the sewage was calculated. The effect of the return sludge (less than 3 per cent) was assumed to be negligible. Uniform air diffusion, that is, a uniform rate of air per lineal foot of aeration tank, was also assumed. This, we know, is far from correct, but we had no means of determining otherwise except by observation.

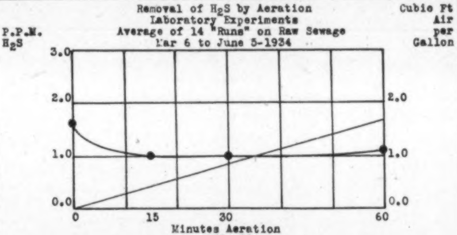

FIG. II

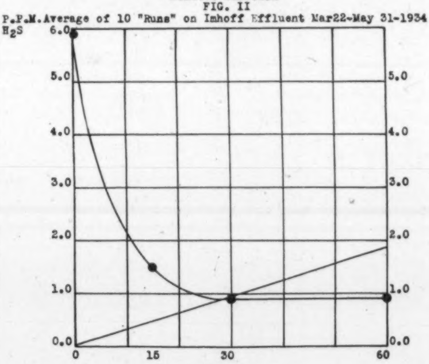

FIG. III

Using the average results for the four batteries would tend to approach average conditions. The same thing might be said for the sewage flow, as some batteries undoubtedly received more than others.

In all 33 "runs" comprising 198 determinations were made. The results are shown graphically in Figure I.

It will be seen that for H_2S removal in our plant the economic time seems to lie somewhere in the neighborhood of 150 minutes, using 0.25 cubic foot of air per gallon.

A series of laboratory experiments were run to study the rate of removal of H_2S by aeration.

Method.—Five-gallon bottles were cut off so as to give a straight-sided cylindrical jar, 12 inches high and 10¼ inches in diameter. Three gallons of the sample to be tested was placed in each of three of these jars. Air was introduced into these samples from the regular air supply lines at the plant, by means of home-made diffusers. The diffusers were made by cutting off the bottom part of a tin can 4 inches in diameter to a height of 2½ inches. Circular pieces of Filtros plates, 3½ inches in diameter were cut from a regular 12 × 12 × 1½-inch plate so as to obtain pieces having the same porosity. These were then cemented in place with ordinary Portland cement so that their top surfaces were flush with the top of the can, thus leaving an air space beneath the

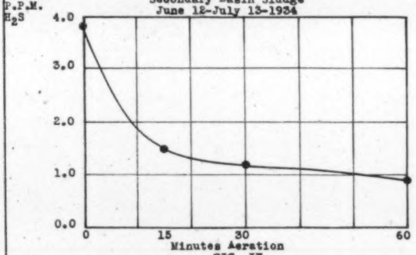
Removal of H_2S by Aeration
Average of 7 "Runs" on
Secondary Basin Sludge
June 12-July 13-1934

FIG. IV

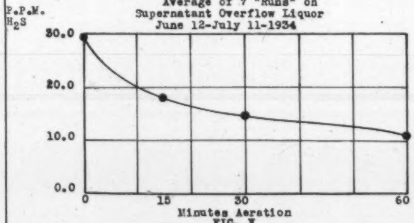
Average of 7 "Runs" on
Supernatant Overflow Liquor
June 12-July 11-1934

FIG. V

plate. At the side and near the bottom a piece of ¼-inch pipe was inserted and soldered, thus providing for the introduction of air.

A 3½-inch diameter of diffuser plate has an area of 9.6 square inches, while the surface area of the liquid in the jars was 82 square inches. Thus there was a plate to surface area ratio of 1 to 8.5.

The submergence (distance from top of diffuser to top of liquid) was 6¾ inches.

Three jars of the sewage were used for a test. One sample was aerated for 15 minutes, a second sample for 30 minutes and the third for 60 minutes. The rate of air supplied was measured by a 5-light gas meter and the air was equally distributed among the three samples, by keeping a constant pressure over a fixed orifice.

A series of 14 "runs" was made on the raw sewage. The results are shown on Figure II.

It will be noted that with about 0.4 cubic foot air per gallon, applied in an aeration period of 15 minutes, the H_2S was reduced to the minimum.

Ten "runs" made on Imhoff tank effluent are shown in Figure III. The minimum was reached in 30 minutes with 1 cubic foot of air per gallon.

Seven "runs" on secondary basin sludge are shown in Figure IV. and seven "runs" on digester overflow liquor are shown in Figure V.

SLUDGE DIGESTION AT MEADVILLE, PENNSYLVANIA*

By C. H. Young and R. L. Phillips

District Engineer, Pa. Health Department, and City Engineer, Meadville

The Meadville sewage treatment plant comprises primary treatment with chlorination during the summer. The plant includes a pump station, screen chamber, rectangular settling tanks with sludge-collecting mechanism, heated sludge-digestion tanks with gas collection, glass-covered and open sludge beds, control building, and other appurtenances. The effluent is discharged to French Creek.

Meadville has a resident population of 17,000, which does not include some 500 students at Allegheny College. The plant is designed to receive 2.4 m.g.d. and the settling tanks will have a 3-hour detention period on that flow. The average dry weather flow is now about 1.7 m.g.d. The sewer system is of the separate type, and records of the city engineer's office show that over 97 per cent of the population of the city is connected to the plant. There are no industrial wastes of any moment.

The plant has been designed to provide considerable flexibility. During the past ten months the digesters have been operated upon the basis of stage digestion.

Sludge Digesters.—Two concrete digestion tanks are provided, each 35 ft. in diameter by 20 ft. deep. Each is equipped with a floating cover for gas collection, and each has a capacity of about 20,000 cubic feet. The outside of the tank walls is insulated with 3-inch hollow tile "seconds," over which is plastered a ½-inch coat of cement mortar. The floating covers are insulated with 1-inch planks, 1 inch of cork, and 2 inches of concrete. The tanks are partly elevated and are banked with earth as a means of further decreasing heat losses. During the wet months of the year the hoppers of the tank are in contact with ground water.

One tank is equipped with three, and the other with five, spiral water coils, of 2-inch wrought-iron pipe. The coils are 1½ feet from the walls, are staggered, and are about 2 feet above the junction of the bottom and the walls of the tanks. Heat is applied to the tanks by means of a gas-fired water heating system which uses as fuel a part of the sludge gas collected from the digesters. The complete heating system comprises a separate gas meter for the water boiler, hot water meters, two low-capacity water pumps, recording and indicating thermometers on the feed and return lines, and recording thermometers, the bulbs of which terminate at about the mid-points of each digester.

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* Presented before the Eighth Annual Conference of the Pennsylvania Sewage Works Association, State College, June 29, 1934.

Operating Procedure—Stage Digestion.—Fresh solids are pumped each morning from the settling tanks by means of a plunger pump to the measuring or concentrating tank, located in the control building. The sludge is inspected, sampled, temperature secured, limed if necessary, and the amount measured by actual volume in this tank. Most of the time the fresh sludge is allowed to concentrate for a period of one to three hours, which reduces the volume 16 to 40 per cent. The fresh sludge is then pumped to No. 1 digester by means of a four-speed centrifugal pump.

The usual procedure is to withdraw fresh sludge from each settling tank until the moisture content approaches 98.7 to 99.0 per cent. All the fresh sludge is pumped to No. 1 digester, and every day, or every other day, supernatant or sludge is drawn from this tank to No. 2 digester. Sludge or supernatant is withdrawn from No. 2 digester as needed.

Beginning in October, 1933, and extending through to April, 1934, the temperature of No. 1 digester was maintained between 88° and 102° F., most of the period being above 93° F. Since that time the same basis of operation has been continued except that a lower temperature—83° to 86° F. has been maintained in No. 1 digester.

Suspended Matter and Solids Added to the Digesters.—Suspended solids determinations of the raw and settled sewage have been made for only a four-day period. Composite samples of the crude sewage and settling tank effluent were obtained by collecting hourly samples during the 24 hours of each of these days. These results indicate that the suspended solids of the raw sewage averaged 200 p.p.m. The suspended solids of the effluent varied from 54 to 70 p.p.m. The sewage flow during the test period averaged 1.53 m.g.d.

Tests for settleable solids (2 hours) showed a removal of 99 per cent. These results compare well with the daily catch samples secured during the peak daily flow.

Once or twice a week, fresh sludge samples are collected at 5-minute intervals as fresh sludge is being pumped from the settling tanks to the concentrator. These are analyzed for moisture and volatile matter. The solids content of the fresh sludge as determined by these tests has varied from 3.1 to 8.35 per cent, averaging about 4.5 per cent. The volatile content of the dried fresh sludge varies, with few exceptions, from 71.8 to 84.3 per cent, averaging about 78.5 per cent.

Temperature and pH.—Heat has been applied to No. 1 digester by means of the hot water coils. The only heat added to No. 2 digester has been the warm sludge or supernatant displaced from No. 1 digester.

During the past winter there was sufficient heat added from this source to maintain a tank temperature in No. 2 digester between 79° and 83° F.

At seven- to ten-day intervals temperature readings have been secured by means of a portable thermometer with 23 ft. of flexible cable connected to the bulb, and samples of sludge were secured from No. 1 digester at 3 ft. vertical intervals. The sludge samples were analyzed for moisture and organic solids. These results showed that there was no distinct sludge line at any time, that there was a separation of solids with a higher proportion of solids at the top and bottom of the tank, that the top solids contained the greatest amount of volatile material and that while there was a good distribution of temperature horizontally the 2 to 4 ft. of sludge underlying the cover had a temperature of from 5° to 12° F. lower than the tank temperature.

The pH of sludge in No. 1 digester averaged 6.9, whereas the No. 2 tank sludge averaged about 7.2. Very little lime was added.

Gas Production.—Continuous gas production records were not obtained due to several causes, such as the blowing out of No. 1 oil seal due to gas production (until the oil seal was raised 12 inches), freezing of the gas lines during the abnormally cold winter, venting of the gas at night during the abnormally cold period until the gas lines were insulated, and lastly, three periods when no gas was produced, as will be discussed later. Excepting these periods the amount of gas produced was equivalent to 17,500 cubic feet per day, or one cubic foot per capita. Eighty-five to 92 per cent of this gas was produced in No. 1 digester, the remainder being produced in No. 2 digester. The gas is measured at 3 to 3½ inches water pressure, each tank being provided with a separate gas meter.

Weekly determinations of CO_2 were made, with results varying from 29.3 to 35.1 per cent. There is practically no difference in the CO_2 content of the gas from the two digesters. Gas from No. 1 digester was analyzed for heating value and the results indicated 688 B.t.u. per cubic foot.

On a yearly basis, probably not more than 25 per cent of the gas produced would be required for sludge heating.

The solids content of No. 1 digester bottom sludge varied from 5 to 12 per cent, depending upon the operation of the tank, whereas the supernatant or middle sludge varied from 1.5 to 6.5 per cent solids. The volatile content of No. 1 digester bottom sludge averaged 51.5 per cent, whereas the organic content of the middle sludge was between 52 and 60 per cent. The No. 2 digester sludge had a solids content of from 10 to 12 per cent, with a volatile content of approximately 47.5 per cent.

Generally the supernatant from No. 2 digester was returned to the influent of the settling tanks. When the solids content of the supernatant exceeded about .45 per cent, as it did during several periods, this material was either concentrated and returned to No. 2 digester, or was wasted on the sludge beds. Unfortunately the top supernatant withdrawal line in the No. 2 digester is 5 ft. below the full depth level of the tank. This is a serious handicap to securing the clearer top liquid.

Operating Difficulties.—Scum was always present in the No. 1 digester and has varied from as little as 1 ft. to as much as 10 ft. in depth. No scum has been observed in No. 2 digester at any time. It has been found necessary to break up the scum in No. 1 digester at intervals varying from one to two weeks. This is done by circulating supernatant or middle sludge for about 30 minutes through the centrifugal pump, and hosing through the four sample holes and the gas dome. This procedure has proved effective and has also resulted in helping to maintain a more uniform tank temperature.

Hosing the scum, especially when not done regularly during the cold winter months, produced an operating upset. On three occasions hosing the colder top scum produced a sudden decline in tank temperature and, for two to four days thereafter, an almost complete stoppage of gas production. Gradually the gas supply would return to normal. Principally because of this experience, it was decided to operate at a lower tank temperature as a means of better controlling fluctuations.

Heat Losses.—The following table gives the data in connection with operation of the heating plant and the sludge digestion tank losses during two winter months—January and February.

Tank temperature	89° to 97° F.
Air temperature	23°
Average temperature fresh sludge	48°
Cubic feet fresh sludge added per day	740
Temperature difference digester feed and return water	18.5°
Gallons hot water circulated per day	21,500
B.t.u. heat added per day	3,315,000
Per cent heat utilized	71%
Per cent heat lost	29%
Coil heat transmission	17.7 B.t.u. sq. ft. per hour per 1° F. temperature difference

Present Operation.—The present operation is the same as before, except that No. 1 tank temperature has been maintained between 83° and 86° F. This temperature, plus possibly a higher fresh sludge temperature and regular scum hosing, has produced much more uniform tank temperatures. The maximum vertical temperature variation as indicated by the regular temperature soundings has not exceeded 4° F., and this is principally in the 2 ft. of sludge immediately underlying the cover. Gas production during this period has averaged in excess of

18,500 cubic feet per day and reductions of volatile matter in both the digesters are practically the same as before. No. 1 tank continues to produce from 85 to 92 per cent of the total daily gas.

The supernatant from the second-stage digester has been gradually improving, and it is only recently that this has been consistently satisfactory, due largely to the inability to withdraw the top liquid from the tank.

The sludge as drawn to the drying beds is well digested and dries rapidly without odor.

Conclusions

As a result of this operating experience the following conclusions have been reached:

1. Better distribution of heat, especially at higher temperatures, would be secured by installation of spiral coils extending from the top to the bottom of the tank.

2. Positive facilities for scum breaking must be provided in No. 1 digester, and it is also desirable to be able to withdraw occasionally part of the top floating material to the drying bed.

3. It is questionable if a designer of a digestion tank is justified in highly insulating a tank in addition to an earth embankment, as the heat lost by withdrawing supernatant and sludge exceeds, during the winter months, by almost three times the amount of heat lost from the tank walls and cover.

4. Digestion, as measured by gas production and volatile matter reduction, is apparently as rapid at about 84° F. as at about 94° F. This raises a question as to whether there is any operating advantage in the higher temperature.

Discussion

Mr. Phillips: There are one or two minor details about the plant that might be mentioned. One word of caution about the floating covers. If you use floating covers, design your own gas lines. Our gas lines from the covers were inadequate and we had trouble protecting them. We raised the gas line about 12 inches on the first-stage tank and it solved the problem by bringing up the pressure.

We have one or two things in connection with the settling tanks which are a bit novel. We have adjustable weirs on the inlet end of the tank. This was Mr. Young's idea and it has worked very well. If you want to experiment at any time it gives you an opportunity to adjust the weirs very readily. We also have a perforated air line in the influent channel to prevent deposition of solids. This has proved to be a big help in keeping these channels clean.

Mr. Herr: How deep are the tanks?

Mr. Phillips: The sedimentation tanks have a nine-foot depth of sewage.

Mr. F. W. Jones: I would like to inquire regarding the heat losses in the digestion tanks.

Mr. Young: Over a two-month period heating efficiently was computed to be 71 per cent.

Mr. Jones: Is that the heat that goes into the water of circulating coils or is it the amount of heat on a theoretical basis necessary to heat the incoming sludge from its initial temperature up to the tank temperature?

Mr. Young: The heat loss and the heat used were computed. The fresh sludge goes into the measuring tank, the temperature and the volume are read and you know the digestion tank temperature. The difference between the temperature of your fresh sludge and the sludge in your digester, times the weight of your sludge, gives you the B.t.u. required to raise the temperature of the fresh sludge up to that of the tank. That amounted to 71 per cent.

Mr. Jones: That is 71 per cent of the total heat applied?

Mr. Young: That has nothing to do with the boiler efficiency.

Mr. Jones: That is just what I was getting at. Putting it this way. What per cent of the total heat is used—starting way back with your gas, what per cent of that heat is necessary to heat the sludge you add?

Mr. Young: The only way you could determine that accurately would be to have a gas analysis practically every day.

Mr. Jones: For ordinary purposes the composition of the gas doesn't vary a whole lot. I think our experience has shown that the actual heat required to heat the sludge is only about 30 or 40 per cent of what you put in and I am afraid that the 71 per cent efficiency that Mr. Young mentioned is a little high. I think your tank losses are really higher than you think they are.

Mr. Young: They can't be higher.

Mr. Jones: You figure out the actual heat required to heat the sludge and then divide those B.t.u. by the total B.t.u. you start with.

Mr. Young: I will make it a little plainer. The heat that goes in the hot water from the hot water heater to the tank does two things—it raises the temperature of the fresh sludge up to the tank temperature and it also takes care of the heat losses in the tank. Your losses then are the difference between the heat which you put into the tank and the heat corresponding to the temperature maintained in the tank. The tank losses have nothing to do with your boiler efficiency.

Dr. Rudolfs: I was much interested in the study on heat losses because I think that is the third one that has been reported in this country.

I believe that I am correct in saying that the first one was at Freehold and then some studies were published by Mr. Haseltine in California and the third one is by Mr. Young. Another study has been published from Halle in Germany and that constitutes all the knowledge that has been published on heat losses from tanks.

Now I think that we will find a good deal of variation in heat losses from place to place, depending upon the type of installation—whether the earthen bank is of clay or of sand makes a great deal of difference. Mr. Young's tank is insulated at the top. Many tanks are not insulated at the top and I am convinced that a tremendous amount of heat goes through the top in addition to what goes through the sides.

I think Mr. Young is to be congratulated upon this study and I hope that he will continue to compile the results which can be done with the help of your able Chairman. I think that next year we will have a little more comprehensive study of the whole subject. It will stimulate, probably, the accumulation of data in other places in the country and will be of great advantage in the long run.

I think I feel rather that the name chosen by Mr. Young for his digestion tanks is rather unfortunate. Two-stage digestion I have always conceived as being a partial digestion very decidedly on the acid side, followed by a digestion very decidedly on the alkaline side. Now from the results given it appears that what Mr. Phillips has is a digestion tank where he gets about 80 to 90 per cent digestion and then he has an after-digestion plus concentration tank. You get the last bit of gas but it is especially good for concentration and for getting a clear supernatant liquor. So, I think, Mr. Young, you had better hunt for another word instead of two-stage digestion.

Professor Walker: I realize that it is rather foolish sometimes to tell what you think you are going to do but at the same time I will do this for one or two minutes.

We now have under construction at Carlisle a sewage treatment plant in which we have made one or two variations from standard practice up to this time and I refer particularly to the matter of insulation. Insulation has previously been installed only on top of the covers but in this particular job we are also insulating the under surface of the steel covers as well and I do not hesitate to say that we expect to save something like eight or ten thousand B.t.u. per hour by that insulation during the winter months. It remains to be seen, of course, whether our expectations are met. I am risking a little bit now in telling what I think we will do.

Dr. Rudolfs mentioned the matter of heat losses through the side of the tank. There has been a large variation in the figures published and in the figures in use. If you look at the various engineering handbooks you find estimates varying from somewhere around 8 B.t.u. per foot per inch thickness, up to somewhere in the neighborhood of 12 or 13—I won't vouch for the accuracy of these limits.

Some experimental work done here at the College under Professor Hechler's direction indicates that a loss of 14 B.t.u. per hour per inch thickness of concrete is not at all unlikely. These tests were run in duplicate both here and at the Bureau of Mines Laboratory in Pittsburgh. Unfortunately, we have no data as to the exact composition of the concrete and that is one thing in which I am very much interested. I have requested that our Engineering Experimental Station run some more experiments on heat transmission through concrete and at the same time determine the character of the concrete, its density, materials used, and so on. These experiments referred to were run at the request of heating engineers and I suspect that the concrete may not be quite as dense as we try to get when building digestion tanks and, therefore, that the transmission losses may be a little different in a dense concrete from what they were in these series of tests. Some tests show heat losses of 16 to 18 B.t.u. per hour with concrete. There you have a range somewhere in the neighborhood of 6 to 8 on one hand to 16 and 18 on the other. What are you going to use? On the Carlisle job I used 14.

Dr. Rudolfs mentioned, also, the effect which the variation in soil has upon the heat loss and I think that is a very important factor. In this particular job in order to cut down heat loss as much as possible, I specified a cinder fill 16 to 18 inches in thickness extending from the bottom of the tank cylinder to the surface. I didn't bother about the cone in the bottom. I expect that this cinder fill on the side will also reduce the losses. I repeat, again, I realize it is dangerous to say what you are going to do and what you expect to find.

Industrial Wastes

OIL POLLUTION AND REFINERY WASTES *

Report of Committee on Oil Pollution, Conference of State Sanitary Engineers, October, 1934

H. F. Ferguson, Illinois, *Chairman*

Subcommittee on Oil Field Wastes	*Subcommittee on Refinery Wastes*
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Introductory

This is the first written committee report to the Conference of State Sanitary Engineers on Oil Production and Refinery Wastes. It is based largely on replies to a questionnaire sent out by the chairman, a study of the literature by Engineer C. D. Gross, the experience of the Illinois Sanitary Water Board in oil fields and at refineries in Illinois and miscellaneous correspondence in the past between the chairman and some of the other state sanitary engineers who have had similar problems.

This report is not submitted as a complete nor exhaustive treatise on the oil production and refinery waste disposal problem but it is hoped that the inventory presented, together with a review of some of the accomplishments and the bibliography appended, in conjunction with the excellent manuals prepared by the American Petroleum Institute, will be helpful to state sanitary engineers who have now or may have in the future pollution problems caused by such wastes.

Extent of Oil Production and Refineries and Waste Pollution

Reports of the United States Bureau of Mines indicate that in 1933 oil was produced in 19 states [2] and there were petroleum refineries in 32 states.[1]

The annual oil production and the number and capacities of refineries are shown in accompanying map and tables.

Pollution of waters by wastes incidental to the production and refining of oil is widespread but has not resulted in complaints in some states because of fortunate location of waste outlets with respect to uses or volume of the streams. Some states which have not reported objectionable oil pollution may be confronted with this problem in the future due to further expansion of petroleum industries.

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Oil Field Wastes

Table I indicates the total 1933 production of oil by states and summarizes replies from those states which reported pollution by oil field wastes.

The problem of oil field wastes disposal is presented in every oil producing area with varying degrees of severity depending upon the magnitude of production and the relative concentration, composition and volume of brines which accompany the oil pumped from wells.

Effects of Oil Field Waste Pollution

Oil field waste pollution has caused tastes and excessive mineralization in water supplies, tainted flavor and destruction of fish and wild fowl, reduction of aquatic sports, damage to farm crops, lands and livestock.

Water Supplies. "Free" or floating oil has caused oily tastes in surface water supplies and also resulted in objectionable oil coatings upon water purification plant basins, piping and filters. Oil well brines have increased the salt content of streams and even rendered such water unsuitable for domestic, livestock and sometimes industrial purposes.

Contamination of groundwater supplies is quite common in and near oil fields, often because of careless drilling and casing operations or in the case of old fields because of defective and corroded well casings. The contamination results in "oily" or "gassy" tastes and increased salt content of the affected water wells. Some wells have been made salty by the salt water discharge into nearby streams or ponds.

Recreation and Aquatic Life.—The detrimental effects of floating oil upon bathing, boating, fishing and hunting have been experienced in many states. Oil destroys fish spawn and fry thereby reducing fish life and imparts an oily flavor to living fish making them unfit for food.[4]

Waterfowl tend to avoid oil coated waters but occasionally alight in an oil patch, saturating their feathers with oil and frequently perish.[3]

The available data upon limiting tolerances of the various fishes to salts are not conclusive.[6]

Damage to Agriculture.—Oily wastes deposited upon farm lands by stream overflows have destroyed crops and in some cases rendered soils non-productive for years. Destruction of crops and other vegetation and damage to soils by oil well brines have been observed.[6]

Some cattle, sheep and hogs develop a liking for crude oil and suffer adverse physiological effects from its ingestion, either because of its

TABLE I.—*Oil Field Wastes*

Summary of Replies from States Reporting Pollution

State	Oil Produced Million Bbls. (1) 1933	Pollution Caused by		Abatement Obtained	
		Oil Well Brines	Oil and Emulsions	Oil Well Brines	Oil and Emulsions
Arkansas	11.6	—	—	—	—
California	173.	Yes (2)	Yes (2)	Yes	Yes
Colorado	.9	No	No	—	—
Illinois	4.2	Yes	Yes	No	Yes (3)
Indiana	.7	No	No	—	—
Kansas	41.9	(4)	—	—	—
Kentucky	4.6	—	—	—	—
Louisiana	24.6	(5)	—	—	—
Michigan	7.8	(6)	—	—	—
Montana	2.1	—	slight	—	—
New Mexico	14.0	No	No	—	—
New York	3.2	(7)	—	—	—
Ohio	4.3	—	—	—	—
Oklahoma	181.5	—	—	—	—
Pennsylvania	12.6	Yes	Yes	No (8)	some
Tennessee	.006	No	No	—	—
Texas	396.4	Yes	Yes	some (9)	many (9)
West Virginia	3.8	—	—	—	—
Wyoming	11.2	—	—	—	—

(1) From U. S. Bureau of Mines monthly Petroleum Statement P 115, December 1933.

(2) California reported nuisances in a couple of sloughs. Abatement secured by oil separators and piping brine to tide water.

(3) Illinois abated oil pollution by use of earth basin separators. Brine pollution not abated.

(4) Kansas reported one instance of returning brine to a well.

(5) Louisana reported that the State Department of Health has jurisdiction over pollution only if public water supplies are affected or a public nuisance is caused. Other effects are investigated by the Department of Conservation. Monroe, Louisiana impounded a supplemental water supply because of oil well brine pollution.

(6) Michigan Department of Health referred questions to Stream Control Commission. Brine pollution still serious.

(7) New York stated that oil field pollution had not caused complaints to nor required investigations by the State Health Department.

(8) Pennsylvania reported one instance of diverting oil well brines around a water works intake.

(9) Texas reported use of oil traps and pick-up dams for oil separation, storage basins and dilution for oil well brine disposal.

laxative properties or possible toxicity, fail to thrive and have been reported to die as a result.

The toxicity of some well brines has been mentioned[11] but it is believed that deaths of livestock due to actual poisoning with oil well brines are rare except in the case of hogs whose tolerance for sodium chloride is low. A less spectacular but more common form of livestock loss results from the laxative or purgative effects of salts present in oil well brines. The animals involved may lose weight, drop in milk production and in extreme cases where salt concentration was high have eventually manifested severe gastritis, irritation, bleeding and even sloughing of intestinal membranes followed by death unless provided with fresh water.

Approximately one pound of either sodium chloride, sodium sulphate or magnesium sulphate will serve as a purgative for mature cattle. In an instance of alleged loss of cattle due to purgative effects of an Illinois stream contaminated with oil well brines, calculation based upon analyses of the stream water and the assumption that a cow will drink 12 gallons of water daily indicated dosage of over one pound of the above mentioned salts each day.

The apparent lack of information upon the tolerance of farm animals and the precise physiological effects of various compounds is regrettable. Some experimental work done upon rats and small animals[10] unfortunately is not applicable to large animals.

In the following tabulation for consideration of possible toxicity due to sodium chloride only, the reference for toxic doses to horses, cattle and pigs was "Veterinary Medicine" by James Law; for sheep, the Texas Livestock Commission. Data upon normal daily water consumption can be verified from many sources.

Animal	Toxic dose of NaCl	Water consumption gallons per day	
		Normal	Probable maximum
Horse	2 –3 lbs.	10	20
Cow	4 –8 lbs.	12	25
Pig	7 –8 oz.	2	3
Sheep	4½–8 oz.	1	2

It is probable that death of livestock due to a single toxic dose of oil well brines is infrequent but loss due to prolonged purgative action and other physiological effects of such waste has been reported in several states.

Abatement Methods

Disposal of oily wastes and emulsions is probably capable of satisfactory solution under any set of conditions likely to be encountered but satisfactory methods for disposal of oil well brines have been developed only in limited areas and under especially favorable conditions peculiar to particular localities.

Oily Wastes and Emulsions.—The types of separators employed vary from the simplest form of earth basin with submerged pipe outlet used at isolated oil wells, to the more complicated traps and structure of large capacity which in some cases involve aeration and even chemical treatment.[7, 12, 13]

Oil Well Brines.—Disposal methods reported include disposal by evaporation and seepage, by dilution and by return to subsurface formations.

Evaporation ponds have been used for brine disposal in Oklahoma[6] and the combined effect of soil seepage and evaporation was reported to be successful in portions of Texas[7] but these methods are applicable only under special meteorological and soil conditions. Oklahoma reported evaporation of brines for recovery of salts by two small plants but such production is warranted only if brines contain sufficient quantities of rare salts.

Brine disposal by discharge into the Gulf of Mexico was possible for some Texas oil fields and several California fields piped brines to the Pacific Ocean.[6, 12] Storage ponds for impounding brines during low stream stages with subsequent discharge of accumulated brine during high stream flows were reported by Texas.

Successful disposal by injection of brines into "cavity" wells drilled especially for that purpose was reported in one Texas field.[7] The return of brines to subsurface formations is not practiced generally and is probably not feasible except where permitted by special geologic formations.

REFINERY WASTES

The 1933 distribution and capacities of oil refineries by states is given in Table II. A summary of replies from only those states which reported objectionable pollution by refinery wastes is given in Table III.

Decided progress in reduction or abatement of oil refinery waste pollution has followed the formation of the American Petroleum Institute's Committee on Disposal of Refinery Wastes[14] which began cooperative studies in 1929 and whose Manual on Disposal of Refinery Wastes is the best available reference on this subject.[15] Section III of that manual, "Waste Chemicals," now in preparation is expected to present proven methods for abatement of refinery tastes and odors in public water supplies.

Successful methods of separating objectionable quantities of oil from refinery waste have been developed and will not be discussed here.

TABLE II.—*Petroleum Refineries by States*
January 1, 1933
(From U. S. Bureau of Mines Information Circular 6728)

State	Number				Capacity Barrels per Day
	Operating	Shutdown	Building	Total	
Alabama	—	1	—	1	6,000
Arkansas	8	1	—	9	44,800
*California	44	17	—	61	900,735
Colorado	5	4	1	10	7,220
Georgia	1	1	—	2	9,000
*Illinois	9	2	—	11	134,700
*Indiana	5	1	—	6	197,050
Iowa	—	1	—	1	1,500
*Kansas	16	—	4	20	163,505
Kentucky	8	3	—	11	29,400
Louisiana	11	5	—	16	209,650
Maryland	3	—	—	3	55,000
*Massachusetts	2	—	—	2	48,000
*Michigan	5	4	—	9	22,500
Missouri	2	1	—	3	23,500
Montana	12	12	—	24	31,300
†Nebraska	1	—	—	1	60
New Jersey	6	2	—	8	290,000
New Mexico	8	2	—	10	6,250
New York	5	—	1	6	55,600
*Ohio	12	2	—	14	100,110
*Oklahoma	44	14	1	59	324,700
*Pennsylvania	37	7	—	44	254,100
*Rhode Island	2	—	—	2	6,500
South Carolina	1	—	—	1	6,500
South Dakota		—	1	1	40
Tennessee	1	—	—	1	58
*Texas	103	42	6	151	914,035
Utah	2	3	—	5	8,350
Virginia	1	—	—	1	1,500
West Virginia	6	—	—	6	18,000
†Wyoming	12	8	4	24	51,392
Total	372	133	18	523	3,921,055

* Indicates states reporting objectionable stream pollution by petroleum refinery wastes.

† Does not have State Sanitary Engineer.

TABLE III.—*Petroleum Refinery Wastes*

Summary of Replies from States Reporting Pollution

States which Reported Pollution	Pollution Caused Objectionable Effects Upon						Tastes and Odors in Water Supplies				Abatement		
	Water Supplies		Recreation	Aquatic Life	D. O. in Stream	Misc.	Due to		Removed by Water Pur. Plants	Methods of Measuring	Partial or Complete	How Obtained	Methods of Measuring
	Chlorine Demand	Tastes & Odors					Chlorophenols	Other Compounds					
California*			Yes	No data	Yes	Groundwater					C	Piped waste to ocean	
Illinois	Yes	Yes	Yes	Yes	Yes	Livestock	Yes	Sulphur compounds N bases	No	Odor intensity by dilution method	P	Neutralization of caustic waste with acid waste	Odor intensity of wastes and water
Indiana	Yes	Yes	Yes	Yes	Yes		Yes		No	Odor intensity by dilution method	P	Phenol removal	Determination of phenols, chlorine demand and odor intensity of wastes
Kansas	No data	Yes	Yes	Yes	No data		Yes	Nature unknown	No	Physical	C	Impounding wastes	Odor and taste tests of water supplies
Massachusetts*			Yes	No data	No						P	Oil separators	Appearance
Michigan	Yes	No	Yes	Yes	No	Livestock					P	Not stated	Appearance, cessation of complaints

TABLE III.—*Continued*

States which Reported Pollution	Pollution Caused Objectionable Effects Upon						Tastes and Odors in Water Supplies				Abatement		
	Water Supplies		Recreation	Aquatic Life	D. O. in Stream	Misc.	Due to		Removed by Water Pur. Plants	Methods of Measuring	Partial or Complete	How Obtained	Methods of Measuring
	Chlorine Demand	Tastes & Odors					Chlorophenols	Other Compounds					
Ohio*			Yes	Yes	No	Livestock					P	Oil separators	Analysis of wastes and stream water by std. methods
Oklahoma	Yes	Yes	Yes	Yes			Yes	Acid waste	No	Physical	C	Impounding wastes	Improvement of water supply
Pennsylvania		Yes	Yes	Yes	No		No	Sulphur compounds	No	Odor and taste intensity by dilution method	P	Evaporation or neutralization of caustic waste	Odor and taste intensity of wastes, stream and water supplies
Rhode Island*			Yes	Yes	No data						C	Oil separators	Appearance, cessation of complaints
Texas	Yes	Yes	Yes	Yes	Yes		Yes	Salt and oil waste	No	Not stated			

New York reported intermittent high chlorine demand and objectionable tastes and odors in Niagara River which receives refinery wastes. Further investigation is needed.

* No public water supplies involved.

Experience indicates that refinery waste pollution has caused increased chlorine demand and tastes and odors in public water supplies, damage to bathing and other recreational areas, tainted flavor and destruction of fishes, shellfish and other aquatic life, ruination of waters for livestock and depletion of dissolved oxygen of receiving waters.

Increased Chlorine Demand of Public Water Supplies by Refinery Wastes

Five states reported experience with this difficulty. Refinery wastes which possess high chlorine demand, will if discharged in batches or into waters with changing volume cause a fluctuating chlorine demand of the receiving waters with consequent danger of inadequate sterilization of drinking water even with unusual care in checking chlorine residuals at water purification plants. A water-borne epidemic last year at Niagara Falls, N. Y., caused by industrial wastes affecting normal chlorination is an example of the danger when any wastes cause a change in the chlorine "demand" of the water. A cooperative study of chlorine demands of refinery wastes is now being made by the State of Indiana and the City of Chicago under the direction of Chemist John R. Baylis, Chicago.

Tastes and Odors in Public Water Supplies by Refinery Wastes

Soluble malodorous compounds found in refinery wastes are too numerous and complex for presentation here but those most objectionable may be classed in three groups as phenolic bodies, organic sulphur compounds (including mercaptans) and nitrogen bases.[15]

Sources.—Phenols and complex organic sulphur compounds may be removed from intermediate or final refinery products by caustic scrubbers, the liquid wastes from which are very obnoxious and if discharged directly into a stream cause disagreeable tastes and odors in the water.

Nitrogen bases may be removed from oils and other products by acid treatment, the wastes from which are capable of causing objectionable tastes and odors in the receiving stream although usually of less intensity than those due to phenols and sulphur compounds.

Methods of Measuring.—With the exception of phenols, quantitative determination of taste and odor producing compounds was not reported by any state. It has been found more practical to evaluate odor intensity of the wastes, receiving stream and water supply by determination of the threshold number [16, 17, 18] or pO value [19] than to attempt quantitative analysis. The relative effectiveness of abatement procedures has been measured by reduction of odor intensity.

Removal by Water Purification Plants.—Although some reduction of tastes and odors was obtained at various water purification plants by aeration, pre-chlorination and treatment with activated carbon and adsorptive clay, no state reported complete success by these methods.

Abatement Methods.—Partial or complete abatement of taste and odor difficulties was reported by 5 states.

An Illinois refinery installed a neutralizing process which reduced the threshold number of its wastes from approximately 15,000 to about 500 and apparently has eliminated the objectionable tastes and odors previously experienced in a downstream public water supply. The treatment, which is applied to the entire flow of cracked distillate, includes a stabilizer (still) to remove hydrogen sulphide and fixed gases, caustic scrubbing, acid treatment and finally neutralization of caustic wastes with acid wastes to effect segregation of obnoxious, malodorous compounds in an oil layer which is burned. The caustic scrubbing converts the so-called "acid oils" into sodium phenolates, mercaptides, napthenates, etc. The acid treatment removes nitrogen bases from oils.

Indiana reported a 90 per cent removal of phenol bearing wastes by one refinery and other abatement work still in progress.

Kansas[9] reported successful abatement by one refinery which constructed a 65 acre impounding basin 14 feet deep with sufficient capacity to hold one year's wastes. Impounded wastes are released during flood stages.

Oklahoma referred to similar impounding procedure in that State as having abated taste and odor difficulties, of some water supplies.

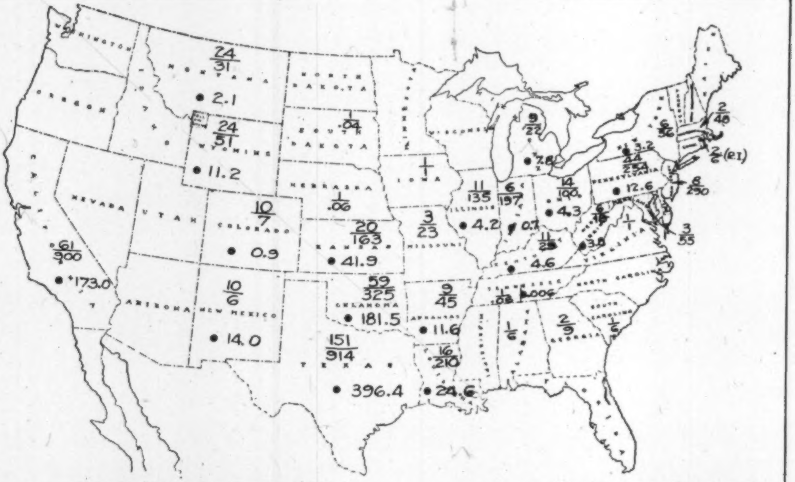
Pennsylvania stated that abatement methods there included, "Segregation of oily wastes from surface waters and treatment in efficient separators for removal of oil; evaporation or neutralization and 'hot blowing' treatment of caustic wash waters for removal of mercaptans and other malodorous sulphur compounds."

Miscellaneous Effects of Refinery Wastes

Recreation and Aquatic Life.—The detrimental effects of oil wastes upon bathing beaches are self evident. Such pollution also interferes with or discourages boating, hunting and fishing. Oil refinery wastes can render fish and shellfish unfit to eat because of the objectionable flavor imparted to the flesh and in extreme cases has caused destruction of aquatic life.[3, 4]

Dissolved Oxygen Depletion.—Three states reported serious depletion of dissolved oxygen in waters which received refinery wastes. Determination of 5-day biochemical oxygen demand of several grab samples of waste from two Illinois refineries indicated population equivalents of about 1600 per thousand barrels of oil refined.

Livestock Watering.—Two states called attention to despoilment of streams for livestock watering and one state reported loss of livestock due to refinery waste.


Washington
Oregon
Califa
61/900
173.0
Nevada
Idaho
Montana
24/31
2.1
Wyoming
24/51
11.2
Utah
Colorado
10/7
0.9
Arizona
New Mexico
10/6
14.0
North Dakota
South Dakota
1/.04
Nebraska
1/.06
Kansas
20/163
41.9
Oklahoma
59/325
181.5
Texas
151/914
396.4
Minnesota
Iowa
1/1
Missouri
3/23
Arkansas
9/45
11.6
Louisiana
16/210
24.6
Wisconsin
Illinois
11/135
4.2
Indiana
6/197
0.7
Michigan
9/22
7.8
Ohio
14/190
4.3
Kentucky
11/25
4.6
Tennessee
1/.03
.006
Mississippi
Alabama
1/6
Georgia
2/9
South Carolina
1/5
North Carolina
West Virginia
6/15
3.8
Virginia
1/1
Pennsylvania
44/254
12.6
New York
6/56
3.2
2/48
2/6 (R.I.)
8/290
3/55

OIL REFINERIES AND CAPACITIES BY STATES (1933)

Numerator indicates number of Refineries. Denominator indicates Total capacity in thousands of barrels per day.

PETROLEUM PRODUCTION BY STATES (1933)

● Figure indicates millions of barrels of oil produced in 1933.

REFERENCES

1. ''Petroleum Refineries, Including Cracking Plants, in the United States.'' *Information Circular* **6728,** U. S. Bureau of Mines.'' June, 1933.
2. ''Monthly Petroleum Statement,'' p. 115, U. S. B. M. December, 1933.
3. ''Pollution of Oil of the Coast Waters of the United States.'' Report of Investigation, *Serial* **2658,** U. S. B. M. December, 1924.
4. ''Effect of Oil Pollution of Coast and Other Waters on the Public Health.'' *Reprint* **936,** U. S. P. H. S. 1924.
5. ''The Control of Oil Pollution in Rhode Island.'' By Stephen DeM. Gage. *Bulletin of Board of Purification of Waters.* 1924.
6. ''Disposal of Oil Field Brines,'' U. S. B. M. *Report of Investigation* **2945.** June, 1929.
7. ''Some Methods of Separating Oil and Water in West Texas Fields and the Disposal of Oil Field Brines in the Hendricks Oil Field, Texas.'' U. S. B. M. *Report of Investigation* **3173.** May, 1932.
8. ''The Evaporation and Concentration of Waters Associated with Petroleum and Natural Gas.'' U. S. G. S., *Bulletin* **693.**
9. ''The Problem of Oil Field Brine Disposal in Kansas.'' By Earnest Boyce, Director, Kansas State Water Laboratory. 1932. (Mimeographed.)
10. ''Saline Drinking Water.'' *Science,* New Series, **71,** 1834. February 21, 1930.
11. ''Occurrence of Barium in the Ohio Valley Brines and its Relation to Stock Poisoning.'' By C. D. Howard. West Virginia Agri. Exp. Sta., *Bulletin* **103.** 1906.
12. ''Solving Oil Field Waste—Disposal Problems.'' *Eng. News Rec.,* **102,** 795. May 16, 1929.
13. ''California Cleans up Oil Pollution of Public Waters.'' By C. W. Geiger. *Municipal Sanitation,* **5,** 305–306. September, 1934.
14. ''Disposal of Refinery Waste Waters.'' By W. B. Hart. *Industrial and Engineering Chemistry,* **26,** 965–967. September, 1934.
15. ''Manual on Disposal of Refinery Wastes,'' American Petroleum Institute. Section I, ''Waste Water Containing Oil.'' Second Edition. 1933. Section II, ''Waste Gases and Vapors.'' First Edition. 1931. Section III, ''Waste Chemicals'' (not completed).
16. ''Procedure for Making Odor and Taste Determinations.'' By J. R. Baylis. *Water Works and Sewerage,* **79,** 425–426. 1932.
17. ''Procedure for Making Odor Determinations.'' By Oscar Gullans. *Journal American Water Works Association,* **25,** 974–981. 1933.
18. ''Quantitative Determination of Odor in Water.'' By C. H. Spaulding. *American Journal Public Health,* **31,** 1038–1039. 1931.
19. ''On the Determination of Odors and Tastes in Water.'' By Gordon M. Fair. Harvard Engineering School, *Publication* **108.** 1934.

Editorial

FOREIGN FRIENDS AND AFFILIATES

The growth of our Federation in the United States has been gratifying, but even more significant has been the growth of foreign associations that have affiliated with the Federation. In this issue we welcome the first contribution from the Canadian Institute on Sewage and Sanitation (page 122), of which Mr. Albert E. Berry is Secretary. We also present the first paper from the group, by Mr. Storrie, describing the Kitchener, Ontario, plant (page 82), one of the most modern and complete in Canada.

Canada has much to contribute to the annals of the Federation, as reflected in THIS JOURNAL. Ontario has various new and interesting sewage treatment plants, at North Toronto, York Township, London and elsewhere, and the other provinces, particularly Manitoba, will soon have many modern sewage plants. The writer several years ago inspected probably the most northerly activated sludge plant on this continent, at the Hudson Bay Mining Company, Flin Flon, Manitoba, far up in the muskeg country, five hundred miles north of Winnipeg. Mr. Robert Phelan, manager of the company, foresaw the need for modern sanitation even in the frozen north, and installed the plant when the mine and smelter were inaugurated.

Farther from home, we call attention with pleasure to the two British associations affiliated with the Federation (pages 119 and 121). The President of the Institute of Sewage Purification, Mr. John H. Garner, has been a true friend of our Federation, and has endeavoured to cement friendly relations. Mr. Garner heads the most active and largest River Board in England, and has contributed much to the advancement of research and practice in sewage treatment. Dr. H. T. Calvert, of the British Ministry of Health, has also been a friend of the Federation in England.

As the Secretary of the affiliated British Institution of Sanitary Engineers, we note the name of Mr. A. D. Hamlyn. The family names of Hamlyn and Hamlin are among the oldest and most respected in sewage treatment practice in Britain. We in America have recently had the pleasure of a visit of one of the Hamlin "boys," Dr. John Hamlin, Chief Engineer of Johannesburg, South Africa. Those who met Dr. Hamlin individually, and during his visit with the New York Association, will not forget his delightful personality and his professional attainments. Far off, in that glamorous diamond and gold-producing city of Johannesburg, Dr. Hamlin has developed an admirable morale of staff, an up-to-date sewage disposal system, and an outstanding research organization under the guidance of Mr. Harold T. Wilson, who worked in Dr. Ardern's laboratory at Manchester when activated sludge was discovered by Wm. T. Lockett, still at Manchester.

South Africa also has another British engineer at Cape Town, Mr. T. P. Francis, whose book *Modern Sewage Treatment,*[*] is well known in America.

In Germany, Dr. Karl Imhoff is best-known to American sewage works engineers. He has frequently visited in this country, his most recent visit being last fall, during September and October. It is with great regret that we note his retirement from management of the Ruhrverband. His retirement in no way lessens the glory of his achievements as the dean of German sanitary engineers. Besides Dr. Imhoff, we have friends in Germany in Dr. Heilmann of Halle, Drs. Prüss, Bach and Sierp at Essen, and others.

In conclusion, we may assure these foreign friends that the Federation appreciates their friendship. The Federation is now represented by 19 local associations in the United States, covering 25 states with a total population of 89 millions. The growth has been steady and representative of American progress in sewage treatment. May the present cordial relations abroad grow and foster a greater spirit of cooperative endeavour in advancing sanitary science.

F. W. M.

EDITOR'S NOTE

Harry F. Ferguson, Chief Engineer of the Illinois State Department of Health, died suddenly of a brain tumor at Chicago, January sixteenth. He had been ill for several months but his death was a shock to his friends. He was a past-president of the Central States Sewage Works Association, and held many other offices in associations and committees. A report prepared under his direction is published in this issue (page 104). Harry's many friends will sorely miss him.

Proceedings of Local Associations

OFFICERS OF LOCAL ASSOCIATIONS MEMBERS OF FEDERATION

Arizona Sewage Works Association

President: Walter Johannessen, Williams.

Vice-President: John A. Carollo, Phoenix.

Secretary-Treasurer: Jane H. Rider, Tucson.

Representatives, Board of Control: M. R. Tillotson, Grand Canyon; Dario Travaini, Phoenix.

California Sewage Works Association

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Second Vice-President: E. A. Reinke, Berkeley.

Secretary-Treasurer: F. D. Bowlus, Los Angeles.

Directors: F. A. Batty, Los Angeles; L. B. Reynolds, Palo Atlo; W. A. Allen, Pasadena; A. G. Darwin, San Francisco; J. F. Smith, San Francisco.

Representatives, Board of Control: C. G. Gillespie, Berkeley; R. F. Goudy, Los Angeles.

Central States Sewage Works Association

President: M. Starr Nichols, Madison, Wis.

First Vice-President: O. M. Leonard, Frankfort, Indiana.

Second Vice-President: H. E. Babbitt, Urbana, Ill.

Secretary-Treasurer: Gus H. Radebaugh, Urbana, Ill.

Representatives, Board of Control: Robert Cramer, Milwaukee, Wis.; Harry F. Ferguson, Springfield, Ill.

Federal Sewage Research Association

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Vice-President: F. R. Shaw, Chicago, Ill.

Secretary-Treasurer: E. C. Sullivan, Cincinnati, Ohio.

Executive Committee: J. K. Hoskins, Cincinnati, Ohio; F. R. Shaw, Chicago, Ill.; E. C. Sullivan, Cincinnati, Ohio; H. B. Hommon, San Francisco, Cal.; P. D. McNamee, Cincinnati, Ohio.

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Secretary: J. B. Croll, Surrey.
Treasurer: C. H. Ball, Manchester.
Representative, Board of Control: J. H. Garner, Wakefield.

Iowa Wastes Disposal Association

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Vice-President: A. H. Wieters, Des Moines.
Secretary-Treasurer: Lindon J. Murphy, Ames.
Directors: Bert Schrack, Oelwein; J. F. Jacobson, Hampton.
Representatives, Board of Control: Max Levine, Ames; Lindon J. Murphy, Ames.

Maryland–Delaware Water and Sewerage Association

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First Vice-President: L. D. Shank, Dover, Del.
Second Vice-President: J. V. Cannen, Hagerstown, Md.
Secretary-Treasurer: W. A. Blohm, Baltimore, Md.
Representatives, Board of Control: Harry R. Hall, Hyattsville, Md.; Abel Wolman, Baltimore, Md.

Michigan Sewage Works Association

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First Vice-President: J. A. Volk, Traverse City.
Secretary-Treasurer: W. F. Shephard, Lansing.
Directors: E. C. Miller, Dearborn; M. P. Adams, Lansing.
Representatives, Board of Control: H. A. Olsen, Ann Arbor; James R. Rumsey, Grand Rapids.

Missouri Water and Sewerage Conference

Chairman: Hugh Brown, Vandalia.
Vice-Chairman: Frank Turner, Cameron.
Secretary-Treasurer: Herbert Bosch, Jefferson City.
Executive Committee: Dr. A. C. Magill, Cape Girardeau; E. E. Wolfe, Hannibal; Harry E. Newell, Webb City; Glenn C. Fox, Marceline.
Representatives, Board of Control: Ralph E. Fuhrman, Springfield; E. S. Glenn, Carthage.

New England Sewage Works Association

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Vice-President: Guy E. Griffin, Cos Cob, Conn.

Secretary-Treasurer: F. Wellington Gilcreas, Albany, N. Y.

Directors and Representatives, Board of Control: Stephen DeM. Gage, Providence, R. I.; Walter E. Merrill, Boston, Mass.

New Jersey Sewage Conference

Chairman: Willem Rudolfs, New Brunswick.

Vice-Chairman: Asher Atkinson, New Brunswick.

Secretary: Richard C. Smith, Glen Ridge.

Representatives, Board of Control: Willem Rudolfs, New Brunswick; Richard C. Smith, Glen Ridge.

New York State Sewage Works Association

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Vice-President: Robert C. Wheeler, Albany.

Secretary-Treasurer: Arthur S. Bedell, Albany.

Executive Committee: E. B. Besselievre, New York City; H. N. Ogden, Ithaca; R. C. Wheeler, Albany; Morris M. Cohn, Schenectady; L. H. Enslow, New York City; Henry W. Taylor, New York City; Charles C. Agar, Albany; Thorndike Saville, New York City; William W. Watkins, Oneonta.

Representatives, Board of Control: E. B. Besselievre, Morris M. Cohn.

North Carolina Sewage Works Association

President: E. B. Burchard, Asheville.

Vice-President: E. H. Moss, High Point.

Secretary-Treasurer: M. F. Trice, Raleigh.

Representatives, Board of Control: H. B. Baity, Chapel Hill; William M. Piatt, Durham.

Ohio Sewage Works Conference Group

President: C. D. McGuire, Columbus.

Vice-President: Floyd G. Browne, Marion.

Secretary-Treasurer: Frank Woodbury Jones, Cleveland.

Representatives, Board of Control: Floyd G. Browne, Marion; C. D. McGuire, Columbus.

Oklahoma Water and Sewage Conference

President: Leon Bennett, Holdenville.

Vice-President: F. L. Bickerstaff, Clinton.

Secretary-Treasurer: H. J. Darcey, Oklahoma City.

Representatives, Board of Control: Clarence Bullen, Blackwell; H. J. Darcey, Oklahoma City.

Pennsylvania Sewage Works Association

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President: R. L. Phillips, Meadville.
First Vice-President: E. B. Wagner, Downingtown.
Second Vice-President: R. R. Cleland, State College.
Secretary-Treasurer: L. D. Matter, Wilkes-Barre.
Editor: J. R. Hoffert, Harrisburg.
Representatives, Board of Control: C. A. Emerson, Jr., New York City; H. E. Moses, Harrisburg.

Sewage Division, Texas Section, S. W. W. A.

President: L. C. Billings, Dallas.
First Vice-President: J. L. Horner, Henderson.
Second Vice-President: Frank M. Murphy, El Paso.
Third Vice-President: A. M. Brenneke, Denison.
Fourth Vice-President: Geo. M. Cook, Tyler.
Secretary-Treasurer: V. M. Ehlers, Austin.
Asst. Secretary-Treasurer: Mrs. Earl H. Goodwin, Austin.
Editor: Tom. C. Green, Austin.
Representatives, Board of Control: V. M. Ehlers, Austin; W. S. Mahlie, Fort Worth.

The Canadian Institute on Sewage and Sanitation

Past President: R. C. Harris, Toronto.
President: W. M. Veitch, London.
Vice-President: G. H. Ferguson, Ottawa.
Secretary-Treasurer: Albert E. Berry, Toronto.
Trustees: N. J. Howard, Toronto; Grant R. Jack, Toronto.
Representatives, Board of Control: Albert E. Berry, Toronto; V. M. Veitch, Toronto.

The Institution of Sanitary Engineers (England)

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Secretary: A. D. Hamlyn, London.

Kansas Water and Sewage Works Association

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Vice-President: F. W. Hoover, Coffeyville.

Vice-President: E. H. Huffman, Topeka.
Vice-President: Frank E. Willey, Marion.
Vice-President: C. A. Sanderson, Lyndon.
Secretary-Treasurer: Earnest Boyce, Lawrence.
Editor: Charles C. Dills, Lawrence.

Northwest Conference on Stream Pollution

Chairman (Acting): Carl E. Green, Portland, Oregon.

CANADIAN INSTITUTE ON SEWAGE AND SANITATION FIRST ANNUAL CONVENTION

Toronto, Ontario, October 18–19, 1934

The First Annual Convention of the newly formed Canadian Institute on Sewage and Sanitation met in Toronto October 18 and 19, 1934. The meeting was well attended, with a total registration of 115. A great deal of interest was manifested by the delegates, and it was obvious that there was a distinct field for such an association.

The program was confined to two days. The first day was devoted to four papers. The first dealt with the design and construction of the sewage treatment plant at Kitchener, Ontario. This consists of preliminary settling tanks and sludge digestion with glass covered drying beds. The large amount of trade wastes reaching this plant creates a great deal of sludge and exceedingly good results have been obtained on the digestion and drying of this material.

The second paper dealt with the design of refuse incinerators. This paper fully covered the field and brought out some very pertinent information for the successful construction and operation of waste disposal plants of this kind. This was followed by a short paper which described the refuse disposal methods used in the City of Toronto.

The final paper of the day dealt with the design of a sewer system. This covered the practice which has been found satisfactory for the City of Toronto and other large municipalities.

The second day of the meeting was devoted to the business affairs of the Institute, a round table discussion and an inspection trip. The round table conference was particularly helpful, with the subject of sludge disposal being foremost. After the luncheon an inspection trip was made to three plants in the city. One showed a new type of vacuum filter. This is a horizontal machine and the sludge is delivered directly to a horizontal belt rather than to a rotating canvas. The extensions to the North Toronto activated sludge plant were next inspected and following this the Symes Road refuse destructor of the City of Toronto was visited.

At the business session the following officers were elected for 1935:

President—W. M. Veitch, City Engineer, London.
Vice-President—G. H. Ferguson, Chief Engineer, Dept. of Pensions and National Health, Ottawa.
Trustees—N. J. Howard, Dir. Water Purification, Toronto. Grant R. Jack, Commissioner of Works, Twp. of East York.
Secretary-Treasurer—Albert E. Berry, Ont. Dept. of Health, Parliament Buildings, Toronto.

ALBERT E. BERRY,
Secretary-Treasurer

SIXTEENTH IOWA CONFERENCE ON SEWAGE TREATMENT

and the

IOWA WASTES DISPOSAL ASSOCIATION

Eighth Annual Meeting

Ames, Iowa, November 1, 2, 3, 1934

The Sixteenth Iowa Sewage Treatment Conference was held at the Iowa State College, Ames, November 1, 2, 3, 1934. Fifty-four city officials, engineers, superintendents and operators of sewage works were in attendance. The program of the Conference was informal, and intended to give instruction on the fundamentals of sewage treatment, as well as practical information on current problems of construction, stream pollution and sewage works operation. The Division of Public Health Engineering, State Department of Health, cooperated with the Engineering Extension Service of the Iowa State College in planning and conducting the course.

The subjects covered in the Conference and the leaders who participated were as follows:

SEWAGE WORKS IMPROVEMENTS

Are Sanitary Improvements Advisable this Year?
Using Relief Labor on Needed Sanitary Improvements.
Planning and Financing Sewage Works.
What to Do with an Obsolete Sewage Treatment Plant.

Open Forum participated in by:

George W. Keller, State Engineer, Iowa Emergency Relief Administration.

A. H. Wieters, Chief Engr., Division of Public Health Engineering, State Dept. of Health.

H. R. Green, Green Engineering Co., Cedar Rapids, Iowa.

C. H. Currie, Currie Engineering Co., Webster City, Iowa.

Sewage Treatment and Stream Pollution

Studies on the Pollution and Natural Purification of Iowa Streams.

Paul J. Houser, Sanitary Engr., Div. of Public Health Engr., State Dept. of Health.

How Much Sewage Treatment is Required?

Earle L. Waterman, Prof. of San Engr. State University of Iowa, Iowa City.

Sewage Works Operation and Control

Laboratory Instruction in charge of William R. Mark, Jr., San Engr. Public Health Engr. Division, State Dept. of Health.

Sewage Treatment Problems

How Can Industrial Wastes Be Handled?

How Important Are Industrial Wastes in Stream Pollution and Sewage Treatment?

What Shall We Do With Creamery Wastes?

Treating Packing Plant Wastes.

The Effect of Drought on Water Supply and Sewage Treatment.

The Mayor's Problems in Connection with Sewage Treatment.

Open Forum participated in by:

Max Levine, Prof. of Bacteriology, I. S. C.,

L. F. Warrick, Chief Engr., Wisconsin State Board of Health, Madison,

P. K. DeVoe, City Engr., Creston,

J. O. Cook, Mayor, Madrid,

M. G. Hall, Hall Engr. Co., Centerville,

John W. Pray, Supt. Water & Sewers, Ft. Dodge,

C. F. McCormack, Mayor, Sutherland.

The Operation of Sewage Works

Things Superintendents of Sewage Works Should Know.

Operation of a Small Plant.

What Seems to cause Foaming at my Plant?

Difficulties in Winter Operation.

Operating Kinks and Short Cuts.

Open Forum participated in by:

E. E. Truckenmiller, Supt. of Utilities, Sibley,
R. A. Davis, City Clerk, Nevada,
Geo. A. Nelson, City Engr., Boone,
H. J. TePaske, Mayor, Sioux Center,
J. F. Jacobson, Supt. Sewage Works, Hampton,
H. J. Michael, Supt. Sewage Works, Pomeroy.

Problems in Handling Storm Sewage.

Paul Winfrey, City Engr. Dept., Des Moines.

Demonstration of Storm Water Run-Off.

In Charge Prof. W. E. Galligan, Civil Engr. Dept., Iowa State College.

Inspection of Sewage Filter Investigations at Ames Sewage Works.

The eighth annual banquet and meeting of the Iowa Wastes Disposal Association was held on Thursday evening, November 1, at the Memorial Union, Iowa State College campus.

Following the dinner a humorous address pointing out the mathematical derivation of the formula for success was given by Jack J. Hinman, Jr., Chief of the Water Laboratory Division, State Hygienic Laboratories. It was greatly enjoyed by the group.

President Earle L. Waterman called a short business meeting of the Association. At its conclusion the following officers were elected for the coming year:

President, Earle L. Waterman, Iowa City.

Vice President, A. H. Wieters, Des Moines.

Director, Bert Schrack, Oelwein.

Director, J. F. Jacobson, Hampton.

Secretary-Treasurer, Lindon J. Murphy, Ames.

Representatives to Board of Control, Max Levine, Ames; L. J. Murphy, Ames.

LINDON J. MURPHY,
Secretary-Treasurer

Reviews and Abstracts

THE SOLUTION OF OXYGEN FROM AIR BUBBLES

By W. D. Scouller and W. Watson

Jour. & Proceedings, Inst. of Sew. Purif., Part 1, 1934, pp. 123–132

Also reviewed with discussions in *The Surveyor,* **86**, 15–16 (1934); **86**, 33–34 (7/13/34); **86**, 510 (11/23/34) and **86**, 567–68 (12/7/34)

The relative rates of solution of atmospheric oxygen in water from surface contact and from air bubbles is a matter of prime practical importance in aerobic sewage treatment processes, especially in the activated-sludge process. Adeney and Becker have determined these maximum rates of surface aeration by a very elegant method and Adeney has developed a formula by which the maximum rate of solution of oxygen can be calculated for any condition of area exposed and volume or degree of saturation, provided the water be kept uniformly mixed. However, there are two opposing views of the rate of oxygen solution from air bubbling through water. Adeney considers that very little oxygen can be dissolved in this manner because of the formation of a saturated film about the bubble which prevents further oxygen transfer. The present authors oppose this view and present experimental data together with references to works of other investigators to support their contention that oxygen is dissolved in water from air passing through the liquid.

Summarizing the evidence of other workers, they state:

"1. There is agreement as to the quantity of oxygen available by passing through exposed surfaces;
2. The evidence for solution from air bubbles is real but has not been brought forward in simple form;
3. The oxygen requirements of activated sludge plants are so large that they cannot be satisfied by surface aeration."

Experiments by the authors are next described in which known volumes of air were passed through a column of distilled water at controlled rates employing apparatus illustrated in the article. The size of bubbles was regulated and determined by counting the number composing a known volume of air under uniform pressure passed through the water column. The same size bubble, 0.24 cm. diameter, was used in all experiments which required two seconds to rise through the 34 cm. column of water. Duplicate runs were made with and without an oil covered water surface, although the results showed no substantial difference.

The experimental data are presented in detail in tabulated form, the computed Table III of which is as follows:

No.	Surface	Volume of Air Used Ccs.	Weight of Oxygen in Air Used Gram	Oxygen Percentage Given Up				Oxy. Abs. per Sq. Metre Bubble Surface per 24 Hours (Bursting Not Included) Grams
				To Bottom Portion	To Top Portion	In Rising 1 Cm.	On Bursting at Surface	
1	Open	184	.0534	2.77	3.07	.121	1.26	204
2	"	180	.0522	2.03	2.70	.088	1.38	150
3	"	175	.0508	2.58	2.76	.112	1.09	190
4	"	202	.0586	2.82	3.07	.123	1.31	207
5	Oil covered	195	.0565	2.64	2.90	.115	1.19	194
6	" "	225	.0653	2.90	3.29	.126	1.41	213
7	" "	187	.0542	2.91	3.12	.127	1.22	215

The experiments were conducted at a temperature of 15° C. It was observed that the top portion of water always contained a greater percentage of oxygen than the bottom both with and without the oil surface layer. This excess was assumed to result from the bubble film on bursting. The average percentage of oxygen dissolved from the bubbles was found to be 0.116 per cm. rise or 3.5 per cent per foot rise. From these data the authors conclude that the oxygen absorbed per unit of bubble surface per 24 hours is three times that absorbed through the same unit of exposed water surface.

These preliminary experiments were confirmed by later experiments reported in a paper read November 22, 1934, before the Institute of Sewage Purification by Messrs. Scouller and Nixon (Surveyor, **86,** 510 (11/23/1934)). This later work on different sized bubbles also proved that the solution of oxygen from air bubbles is directly proportional to the partial pressure of oxygen concentration in the bubbles and to their surface area, and is, therefore, inversely proportional to the diameter of the bubbles. From the results of these experiments, employing Adeney's formula for the relation between oxygen absorbed and the air-water surface, it is calculated that air bubbles are 3 to 4 times more efficient than are air-water surfaces of the same exposed area.

Discussion. The extended discussion of these papers brought out the general appreciation of the applicability of this work to sewage aeration by the diffused air method, although the authors were careful to point out that their paper had nothing to do with any mechanical method of activated sludge treatment.

Mr. W. T. Lockett (Manchester) recalled his earlier experiments in which he had observed marked differences in dissolved oxygen content depending on the size of bubbles passed through sewage. Other experiments and later experience had convinced him of the relationship between aeration efficiency and bubble size which the present paper demonstrated. He also cited the statement of Fowler to the effect that the principal advantage of diffused air resulted from the fact that the velocity of ascending air bubbles was several times less than that of free falling drops of liquid, thus affording a longer contact period for an equal expenditure of energy. He suggested that this ascending rate would be further retarded by the sludge particles with which the bubbles would collide and perhaps frequently divide as a result.

Mr. H. Wilson (Johannesburg) was surprised to learn of the relatively small absorption of oxygen from the surface of the uncovered liquid. He also noted the enormous effect of barometric pressure on rate of oxygen solution and the practical importance of this relationship at aeration plants located at high altitudes such as that of Johannesburg (El. 5500 ft.).

Mr. J. H. Spencer (Northampton) was somewhat critical of the accuracy of the results, partly because of possible inherent defects in the apparatus used. He questioned also the propriety of ascribing the higher oxygen content of the top portion to the bursting of the bubble, rather than to other causes such as enlargement in bubble size as hydrostatic pressure decreased.

Mr. J. Bolton (Bury) questioned the conclusion of the authors that the oxygen requirements of activated sludge plants were so large that they could not be satisfied by surface aeration and which was refuted by the satisfactory operation of plants of the surface aeration type as developed by Haworth. This same view was expressed by Mr. B. R. Henderson who operates a surface aeration plant at Airdrie.

Messrs. H. Kessener and F. J. Ribbius (The Hague) confirmed the conclusion regarding the active part of air bubbles in oxygenation of water and cited the evidence in an annual report to the effect that the oxygen saturation value of water in an air blowing plant was higher than that in a surface aeration plant. Another point brought out was that the efficiency of aeration by air blowing was lower for sewage than for water. Recent experiments with a particular sterilized sewage had indicated a reduction of 60 per cent in oxygenation capacity of an air blowing plant and 35 per cent of a surface aeration plant. They did not concur in the view that surface aeration could not satisfy the oxygen requirements in sewage treatment plants.

J. K. Hoskins

PROPOSALS FOR THE FUTURE DEVELOPMENT OF THE BERLIN SEWAGE MANAGEMENT

By Dr. Ing. Erich Weise

Gesundh. Ing., **57**, 248 (1934)

The sewage of Berlin, except for that purified in the Stahnsdorf activated sludge plant, is disposed of on sewage farms. Since the first sewage farm in Osdorf-Friederikendorf was put into use more than 55 years ago, the land used for sewage farming has been increased from 1975 to 56,800 acres. In recent years mechanical purification plants equipped for gas collection have been erected at Wassmannsdorf and Stahnsdorf. Part of the settled sewage at Stahnsdorf is further purified by the activated sludge process and discharged directly to the Teltow canal while the remainder is purified on the sewage farms. Early in 1934, construction of an activated sludge plant was started at Wassmannsdorf. Part of the effluent from this plant will be discharged on land to demonstrate the fertilizer value of biologically purified effluents.

From 1923 to 1930 the water consumption of Berlin increased and, although there has been a decrease since 1930, improved economic conditions will cause further increases. The increase in area of the sewage farms has by no means kept step with the increase in water consumption. Just before the war the average load on sewage farms of Alt-Berlin amounted to about 4000 gallons per acre per day but now it amounts to about 6300 gallons per acre per day, when the area of the ditches is excluded. The plans of Hahn made in September, 1928, provide for the construction of six large complete clarification plants within a period of fifteen years, in order to increase the efficiency of the sewage farms. In fifteen years it is estimated that the population will exceed 5,000,000 (present population 4,200,000) and the amount of sewage will reach about 40 gallons per capita per day.

It is of primary importance that the fertilizer value of sewage be used to aid in the agricultural independence of Germany. If one considers that the average annual rainfall on the Berlin sewage farms is 20 inches per year, and that 79 inches of sewage containing 1400 pounds nitrogen, 350 pounds phosphoric acid and 1100 pounds of potassium are added per acre per year, it is easily seen that a great deal of the water and plant food available for agricultural purposes is wasted. According to agricultural authorities an addition of about 12 to 24 inches of sewage per year is correct.

One of the disadvantages of these sewage farms is that Berlin sewage becomes septic before it reaches the farms and causes many complaints on account of disagreeable odors. Another disadvantage is that a large part of the sewage is removed from the drainage area of the Spree River. About 36 per cent of the Berlin sewage farm area is drained to areas not supplying Berlin with water. In addition, about one-third of the sewage is lost through evaporation, so that, of approximately 60 billion gallons of sewage per year, nearly 40 billion gallons are removed from the Berlin water stores.

The use of complete purification plants in connection with the sewage farms will remove some of the present disadvantages of sewage farming. Biological treatment would eliminate the odor nuisances and the effluent not used for agricultural purposes could be discharged directly into the bodies of water feeding the Berlin water supply. The digested sludge could be used as fertilizer and the excess heat obtained from the gas could be employed for heating neighboring hot houses used to grow green vegetables.

G. P. Edwards

THE GERMAN SANITARY DISTRICTS

By Dr. Ing. K. Imhoff

Gesundh. Ing., 57 (1934)

The Prussian laws under which the Emschergenossenschaft was founded in Essen on July 14, 1904, have given a new bent to sewage treatment in Germany. The Emschergenossenschaft builds and operates all sewage purification plants within its boundaries and collects the annual quota from the members, communities and industries. The Emscher law was the model for the other nine districts which have been formed during the last thirty years. These ten districts include over 10,000,000 inhabitants, a sixth of the German population, and an area of 9,600 square miles, a twentieth of the area of Germany. This is explained by the fact that only thickly settled communities are suitable for sanitary districts.

The associations finance their own construction and a capital debt amounting to 134,000,000 RM. has been accumulated by the ten districts. This value does not correspond even approximately to the value of the buildings erected. Although the Emschergenossenschaft, alone, for example, spent over 180,000,000 RM., of which about one-half was spent before the war and two-thirds before the stabilization of the mark in November, 1923, its debt has now been decreased to 32,000,000 RM. The Ruhrverband has the greatest indebtedness, 71,000,000 RM., which, almost without exception, was spent after 1923. The greater part of this debt represents expenditures made for artificial lakes, which are, to a certain extent, self-sustaining. The total construction cost for the ten districts amounted to 300,000,000 RM. This debt has been reduced to 134,000,000 RM. As an annual quota 12,700,000 RM. are collected from the ten districts.

The work is carried on by the individual districts according to their different problems and local conditions. On account of land sinking and sewage pollution the Emschergenossenschaft has been compelled to do a large amount of rebuilding. For example, the entire river course with all its tributaries has been developed into a network of about 220 miles of open sewers carrying the sewage in a fresh condition to the Rhine. Sewage purification plays a subordinate part since only removal of sludge is necessary before the river discharges into the Rhine. In the Ruhrverband the river must be protected from pollution since it furnishes 1,400,000 of its own inhabitants and 2,100,000 inhabitants of other districts with drinking water. Besides 70 treatment plants, about 125 miles of sewers and 15 pumping stations have been constructed in order to bring the sewage to suitable points for purification. Settling tanks are sufficient at most of the treatment plants since, through the construction of the three large artificial lakes, the self-purifying power of the Ruhr has been increased to a point where the degree of purification necessary for its water works can be maintained without artificial biological treatment.

The five older associations are adequately providing for their present needs. Their future work consists in the operation of the existing plants so that they will be able to cope with problems such as the progressive sinking of the ground and the increase of sewage pollution and water needs. The five newer districts have not had time to make up for the neglect in the past and the two youngest have not yet begun their work.

G. P. Edwards

WASTES FROM SUGAR FACTORIES

By Prof. Dr. O. Spengler

Gesundh. Ing., 57, 623 (1934)

The wastes from beet sugar manufacture consist of soaking and wash water and the diffusion and press liquor. It is estimated that about 72 gallons of soaking and wash water, 16 gallons of diffusion and rinse water and about 5 gallons of press water, or, in general, about 96 gallons of waste, are obtained from 100 pounds of beets. During the beet sugar season of 1930–31, 37 to 40 billion gallons of waste resulted from the processing of about 17,600,000 tons of beets. The most harmful substances in the waste are those in solution, as about 80 to 85 per cent of the suspended solids can be removed by settling. By the addition of about 0.01 per cent lime the suspended solids removal can be increased to 98 per cent.

It is estimated that for each 100 parts of sugar, the waste contains about 1 to 2 parts albuminous material, 2 to 3 parts of other nitrogenous compounds, 0.5 to 1 part reducing substances, 1 part pentosan, 0.8 part oxalic acid, and pectin and other substances in smaller amounts. In the diffusion or press liquor is found 0.15 to 0.3 per cent sugar, or about 12.5 to 25 pounds per 1000 gallons and about an equal amount of non-sugar organic matter. The soaking water contains only about 20 to 50 p.p.m. of sugar but the sugar content in wastes from frozen or spoiled beets may amount to as much as 500 p.p.m.

Two methods are available for treatment of the wastes. In the first method the soaking and wash waters are passed through settling tanks, where most of the suspended solids are removed, and the settled liquor is again used for washing and soaking beets. Although the concentration of dissolved solids increases, when the water is reused, experience has shown that the concentration soon reaches a constant value. The press and diffusion liquor should be collected at the highest possible temperature (70° C.), for pulp removal, and run back into the process as quickly as possible. In order to prevent bacterial action, intermittent chlorination is desirable.

The second method may be used where the reuse of the water is not possible. In this case the sugar can be removed by lactic acid fermentation but since this fermentation stops as soon as the concentration of lactic acid reaches a certain value, it is necessary to add a small amount of lime at the end of the first fermentation. The remainder of the sugar can then be converted to lactic acid and the sugar content reduced to practically zero. It is customary to start liming as soon as an acid content of about two grams of lactic acid per liter is reached in the first fermentation tank. About 0.1 per cent lime is sufficient to neutralize about 80 to 90 per cent of the acid and to precipitate about 80 per cent of the albuminous material. In this process, which is known as the double fermentation process, the $KMnO_4$ consumed decreases from about 15,000 to about 3,500 mg. In general, secondary treatment by irrigation is recommended for such purified liquor. Such wastes can still cause small amounts of fungus growths in the streams but this degree of treatment is often sufficient.

According to a method developed by Dr. Nolte in Magdeburg, the press and diffusion liquor is fermented in the first tank as in the double fermentation process. Enough lime is added to the second tank to make the liquor weakly alkaline. About twice as much lime is needed in this process as in the double fermentation process. The purification liquor from the digestion process has a $KMnO_4$ consumed value of about 100 p.p.m. and the liquor obtained is completely stable.

G. P. Edwards

TREATMENT OF SEWAGE AT AMSTERDAM

By P. Nauta

Publieke Werken, 3, 93–106 (1933)

The considerable expansion of Amsterdam after the World War produced important sewerage and sewage treatment problems. When the city appropriated 3,000,000 guilders for a sewerage system in the outer city a part of the expansion "South" was taken into consideration, but not a possible rapid expansion "East" and "West." The sewage of part of "South" is discharged into the Zuiderzee, but it was impossible to accommodate the expansions. For this reason separate plants had to be built and experiments made for the best possible and most economical treatment. In 1923 a sum of 148,300 guilders was appropriated for building Imhoff tanks, trickling filters and final settling tanks for a part of the suburb Watergraafsmeer. In 1925 the sum of 564,000 guilders was appropriated for the building of a plant (capacity for 25,000 people) for the suburb Sloten, similar to the one in Watergraafsmeer. Shortly after completion it appeared necessary to increase the capacity sufficiently for 75,000 people. Although the experience with the completed plants was limited, it was clear that calculations for capacities were insufficient. Several tanks were built for experimental purposes, namely Francke, Oms and Imhoff tanks (the latter covered), heated digestors and submerged contact aerators. The Francke tank required a great deal of labor. The sludge had to be removed, at least twice a day, which caused considerable disturbance so that the liquid had to be pumped back for resettling. The capacities of the tanks were too small and the type of tank used was incorrect for Amsterdam sewage. The separate digestion tank had double walls to prevent heat losses. In 1931 about 192,000 cubic meters of gas was produced, of which 77,000 was used for heating the tank to about 25° C. The operation of the trickling filters showed that, (1) during cold weather the purification was reduced and during freezing weather interrupted; (2) large numbers of filter flies caused nuisance and interfered with purification because of the larva and adults in the effluent. For expansion and new sewage treatment plant in "West" 1,329,500 guilders was appropriated and for "South" 895,000, sufficient for 120,000 people. (The population of Amsterdam is over 800,000 and sewage treatment will be sufficient for about 160,000.)

As a basis for calculation the following estimates were taken: sewage 100 liters (26.4 gal.) per capita, sedimentation time 1½ hours; heated digestion tank capacity 1.75 cu. ft. per capita; sludge beds 0.5 liters per capita per day; trickling filters, daily relation between stone and sewage 1½ : 1. Results of observations and experimentation showed variations in flow, for instance: from 12 M. to 1 A.M. 2.9 per cent of the sewage is received, from 5 to 6 A.M. 0.9 per cent, from 8 A.M. to 8 P.M., from 5 to 6 per cent, and a maximum of 6.3 per cent between 1 and 2 P.M. Sludge in Imhoff cones varied from 2 to 48 c.c. per liter. Tests in certain sections of the city showed that during certain hours as much as 235 c.c. sludge per liter settled. Oxygen consumed varied from 150 to 1,000 p.p.m. The settled sludge contains from 25 to 30 per cent fats. From the settling-trickling filter installation a suspended solids reduction of 95 per cent in summer and 80 per cent in winter is obtained. During 1932 the plant was overloaded so that the results were poorer, namely 90 per cent overall purification (oxygen consumed of effluent 100 p.p.m.).

An experimental activated sludge unit showed that the strong sewage could be treated with an aeration period of at least 20 hours, with presettling 14 to 15 hours, and with pre-aeration (3½ hours) 70 per cent purification was reached, while for complete treatment (95 per cent purification) 11 hours was necessary. With shorter aeration time "bulking" occurred. Difficulties occurred only in the second stage of the process, so that with short aeration continuously, 70 per cent purification could be obtained. This pre-treated sewage could be handled on the trickling filters at rates 7 to 8 times the normal. The method recommended for new installations is: sedimentation (in clarifiers), partial aeration, trickling filters, and separate sludge digestion.

Cost of construction and operation for different installations for a population of 150,000 people are given in guilders as follows:

Type of Treatment	Construction		Operation	
	Total	Per Cap.	Total	Per Cap.*
1. Settling and digestion	608,000	4.05	34,500	23.0
2. Submerged contact aerators, trickling filters, final settling	425,000	2.83	11,900	7.9
3. Trickling filters final settling	550,000	3.70	8,500	5.65
4. Activated sludge	356,000	2.37	34,710	23.0
5. Sludge beds, lab. blowers, buildings, land, piping, etc	434,050	2.89	11,250	7.5
Total cost of 1, 4 and 5	1,398,050	9.31	80,460	53.5

* In cents.

Construction cost and operation estimates are given for a number of smaller plants and different combinations.

WILLEM RUDOLFS

ANNUAL REPORT, GOVERNMENT INSTITUTE FOR PURIFICATION OF WASTE WATERS, 1933

BY H. J. N. H. KESSENER, *Director*

The Hague, Netherlands

The Annual Report deals with (1) sewer rental laws, (2) stream pollution, (3) trade waste treatment, (4) advice given and operation of plants, and (5) research.

1. The constitution and laws in effect in the Netherlands allow communities to charge for collection and treatment of sewage and wastes. A schematic tabulation is given concerning the relative costs between collection, pumping and treatment. The costs include construction, operation, contingencies, repairs and amortization. It is concluded that, in general, charges can be based upon the volume of sewage, especially when only primary treatment is required, and in addition upon the character of the waste when secondary treatment is given. It is recommended that water consumption should be the first consideration, and secondly the built-up area served.

2. The rivers Neuse, Geul, Vecht, Merwede, Yssel, Zaan and a number of their tributaries, as well as the North Sea canal and canals around Groningen, are all more or less polluted. In spite of the rather extended self-purification afforded by the flow from the Niers and Ruhr rivers (Germany) before entering the river Meuse, the water is in a very poor condition at the confluence of these rivers. Fish are occasionally affected by phenols, probably coming from Belgium.

Artificial salmon culture is practiced extensively along the Geul. The industry is in serious danger through the discharge of textile, paper, laundry and other wastes as well as through the discharge of sewage.

3. Trade waste treatment was concerned especially with slaughterhouse, laundry, de-hairing, soda, paper and dairy wastes. A new plant was built at Zaandam to treat slaughterhouse waste by Imhoff tanks followed by activated sludge (surface aeration).

4. Results on the operation of the plant at Winterswijk where paddles are installed in the digestors, are given. The sewage is strong, with an average of 202 p.p.m. suspended solids and 313 p.p.m. B.O.D. in the effluent from the Dortmund tanks. The final effluent averaged 32 p.p.m. B.O.D. and 27 p.p.m. N_2O_5. The average daily sewage flow is 720,000

gal. producing 1,540 cu. ft. gas daily (results for 6 months). Power consumption for the paddles in the digestors was 1,150 watts per tank. Since the paddles turn about 15 minutes daily and the energy required is about 3.5 KW., a power cost of 2c per KWHr. means about $7.00 per year. Results for the treatment plant at Groenlo are given and a discussion of several other projects.

5. In a previous report results on the purification power of an activated sludge installation and the determination of its oxygenation capacity were given. THIS JOURNAL, **6**, 423 (1934). A discussion of the definite relation between oxygenation capacity and purification capacity is presented in connection with statements found in the literature.

SHORT-CIRCUITING OF AERATION TANKS

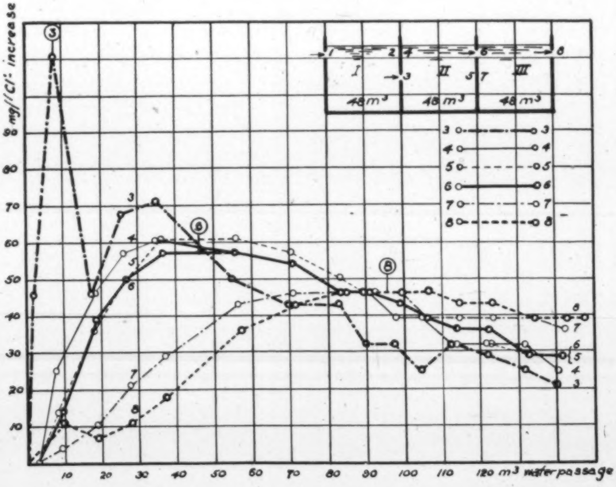
The question of short-circuiting in aeration tanks raised in the previous report, THIS JOURNAL, **6**, 434 (1934), has been further investigated. "One is inclined to explain poor operation by the assumption that when the aeration is good and the purification is poor a circulating lengthwise-moving cone of sewage is present. On the basis of this hypothetical explanation baffles and walls have been placed in the aeration tanks to prevent so-called short-circuiting. The completion of a brush-aeration system gave the opportunity to test the assumed danger of short circuiting. The tank, consisting of three sections, each about 1,900 cu. ft. capacity, was filled with clean water through which a direct and return flow of 635 cu. ft. per hour was maintained. At the entrance of the first section a large quantity of NaCl was suddenly added and chloride determinations made at eight different places during regular intervals. The results obtained for the points 3 to 8 are graphically shown in Fig. 1. The three sections of the tank and the points of sampling are shown schematically in the inset. Section 1 has been left out of consideration because the dispersion of the salt solution was abnormal on account of the high specific gravity of the added salt. With the next trial a dye will be used.

A perusal of the graph shows:

1. The first effect of the added salt solution is noticeable after a short time at all sampling points. After the first appearance of chlorides at the inlet of Section II an increase in chlorides was noticed in the influent and even in the effluent of Section III when only 350 cu. ft. more water had been added. Theoretically, this should have occurred only after 1,900 and 3,800 cu. ft., respectively, had passed through. This rapid passage is not due to most of the tank being "dead," since this "absolute short-circuiting" would be indicated by the maximum chloride concentration. The appearance of small quantities of chlorides is due to "relative short-circuiting," caused by the mixing of the tank con-

tents, whereby the rapid movement of one part of the water is compensated by the slower movement of another part.

2. The velocity of the maximum salt concentration becomes less and less pronounced on account of the more thorough mixing of the salt. The flattening out of the chloride curve is therefore a measure of the "absolute short-circuiting." Between the passage of the peak of sampling points 3 and 6 is a water displacement of 1,375 cu. ft. and between sampling points 6 and 8 a volume of 1,925 cu. ft. Since the compartments had about 1,900 cu. ft. capacity it may be assumed that the absolute short-circuiting in Section II amounted to about 20 per cent and



that it was absent in Section III. On account of the time difference between the sample taking, the passage of the peak of salt concentration could not be determined accurately. The fact that in repeating the experiment minus 20 per cent short-circuiting was found, indicates that in Section II no absolute short-circuiting occurred.

3. The chloride curves form sectional bundles; the maximum concentration does not move smoothly but in jumps. The curves 4, 5 and 6 are practically alike and do not show great differences in comparison with each other, but an appreciable movement in comparison with curve 3. The evenness of the curves shows that water passage was equal at

all points examined, and proves again the absence of absolute short-circuiting. After a short time the curves 4, 5 and 6 come close together, the incoming water is therefore rapidly mixed with the tank contents. The same phenomenon is shown in Section III by the parallel curves 7 and 8 and their movement in relation to curve 6. The movement of the liquid in jumps indicates the value of walls or baffles. Without baffles the rather strong relative short-circuiting (mixing) shown in the section would take place throughout the tank. This mixing is not detrimental and, with changing characteristics of the sewage, it is an advantage. For the tank as a whole the amount of baffling can be easily exaggerated.

The conclusions for an aeration tank of the Kessener type are (*a*) that there is no danger of absolute short-circuiting, (*b*) that mixing (relative short-circuiting) is so strong in the sections, that the placement of several baffles is described.

WILLEM RUDOLFS

TRACING EXPLOSIONS IN SEWERS

BY FRANK W. DOWD

Canadian Engineer, **67,** 17 and 18 (Oct. 23, 30, 1934)

In a paper read before the Engineering Section, Canadian Public Health Association, the author lists some 12 explosions in or related to the sewers of Montreal and caused by gasoline or by gas.

To avoid or minimize future explosions, surveys of the sewer system are made whenever the presence of gas is reported as observed by odor or otherwise. In this there is used a portable J. W. combustible gas indicator. This equipment aspirates the gas from the point under investigation, explodes it in a reaction chamber, and indicates electrically the combustibility of the mix. A sewer manhole can thus be investigated from the surface in about one minute.

In the surveys, start is made at the point under suspicion. Samples are taken (1) at the top of the manhole for illuminating gas; (2) six feet down for methane; and (3) near the surface of the sewage for gasoline. The survey progresses from manhole to manhole until a focal point is located or is bracketed. The source is then ascertained by sleuthing.

Carbon monoxide detectors and safety flame lamps are suggested for further protection.

The author regards the usual regulation to prohibit the discharge of inflammable liquids into sewers as inadequate. He advocates the isolation of storage tanks and their protection by outer leakproof casings with sand between storage tank and casing. Drains to or near to storage tanks should not be permitted. This, the author states, is the safeguard usual in European practice.

Frank C. Tolles

SALVAGE OF SEWAGE STUDIED

By A. M. Rawn

Civil Engineering, **4**, 47 (September, 1934)

A report has been rendered by a joint committee which is studying the where and how and the cost and utility of salvage from sewage. This expression is made to include the recovery of values at the sewage treatment plant (fertilizer, grease and fuel) and also the use of sewage plant effluents, raw sewage and waters grossly polluted by sewage. The report was submitted July 12, 1934 at the Annual Convention, American Society of Civil Engineers. Besides the Chairman, the Committee includes Ernest Boyce, R. R. Lyman, R. F. Goudey and E. A. Reinke.

Circulars relative to the use of sewage for irrigation were sent to the Director of Public Health in 48 states and the District of Columbia. The responses are codified thus:

Replies received		40
Sewage used for irrigation		9
Epidemic human illness traced to sewage irrigation	4	
Infection of cattle traced to sewage irrigation	1	
No health difficulties from sewage irrigation	4	
Polluted water used for irrigation		1
Intestinal disease traced to polluted water irrigation	1	

Generally, the use of sewage or of sewage polluted waters for irrigation was regarded as inadmissible or as repugnant. However, standards for irrigation waters were suggested by one or another state as follows:

Use of Water	*Suggested Quality*
For irrigating vegetables to be eaten raw (one state)	"Well oxidized non-putrescible and reliably disinfected or filtered." Bacteriological drinking water standard.
For cooked vegetables or fodder crops (one state)	Effluent of 30 p.p.m. B.O.D.
For parks and lawns (one state)	Effluent of 20 p.p.m. B.O.D.

The committee is not advocating salvage but is continuing the study.

Frank C. Tolles

WHAT RECLAMATION OF SEWAGE MEANS TO HERINGTON, KANSAS

By J. E. White and F. M. Veatch

Water Works and Sewerage (October, 1934)

Since December 13, 1933, Herington, Kansas, has reclaimed its municipal sewage for use as an industrial water supply with a net return that has very nearly paid all costs of sewage treatment. An unusual set of circumstances has made this possible. The city was ordered by the State Board of Health to install complete treatment for its sewage and the Rock Island Railroad was using a supply for boiler feed that was of unsatisfactory quantity.

A contract was entered into between the railroad and the city whereby the city agrees to furnish water to the company for boiler use. The company is to pay for this water on a sliding rate schedule with a minimum of 5 cents per 1000 gal. delivered into tanks at the railroad shops. The railroad uses from 400,000 to 600,000 gallons per day and the sewage works effluent ordinarily amounts to 350,000 gallons per day. The difference will be made up with untreated water from the city supply or water from other sources.

The sewage treatment plant has no unusual features, being of the activated sludge type with preliminary settling and separate sludge digestion.

From January 1 to September 1, 1934, a total of 99,016,000 gallons of sewage effluent and water was sold with an income of $4950.80. The operating expense during this period was $2094.23. On a yearly basis this represents a revenue of $6601.08 and an operating cost of $2792.28 leaving a balance of $3808.80 toward fixed charges which amount to about $4000.00.

During this period, sewage flows have been abnormally low which imposed an additional cost for pumping creek water, and power costs in the treatment process itself were above normal because the plant was operating at about 56 per cent of capacity.

The plant was financed by the Reconstruction Finance Corporation as a self liquidating project.

R. S. Smith

SAND TRAP FOR SELF-CLEANING OF CANALS AND STREAMS

Public Works, p. 16 (November, 1934)

A flowing stream carrying sediment can be made to clear itself as it flows. Three types of sand traps have been developed by R. L. Parshall, engineer of the U. S. Department of Agriculture, whereby a small part of a stream can be diverted through them to carry out of the main stream a concentrated load of sand, silt and debris.

The traps vary widely in construction, are inexpensive and each is designed for a certain condition of flow. The vortex tube trap is for use in moderately swift streams, the riffle deflector in moderate currents and the grating trap in gentle currents.

The vortex trap consists of a tapered tube in the floor of a flume built in the canal. The tube lies diagonally across the stream and has a wide slit the full length of its upper side, placed level with the floor of the flume. The bed-load of sand and gravel is caught by the whirling body of water inside the tube and conveyed to a discharge outlet in the side or bottom of the structure. Three installations in large canals have proved effective.

The riffle-deflector type consists of a series of curved vanes set in the bottom of a ditch or canal. Each vane is curved into a 90 degree arc of a circle. The vanes, when set in a line normal to the current and properly spaced, will move the bed-load across the stream to an opening in the side wall of the channel, where a small stream carries it out. The device functions well when the vanes can be kept rid of tins, cartons and other trash.

The grating type of trap is relatively new and consists of a series of straight or curved vanes set on the floor of a flume normal to the stream flow and uniformly spaced, with top edges inclined downstream. The sand particles are drawn down behind the top edge of the device and retained there so that they may settle into a receptacle below the floor of the flume.

H. W. Streeter

PORTABLE GRIT CHAMBER FACILITATES SEWER CLEANING

By Chas. C. Agar

Water Works and Sewerage (November, 1934)

The Delmar-Elsmere Sewer District, southwest of Albany, New York, had a great deal of trouble from very fine quicksand entering through breaks in the sewer pipes which in places are laid at depths of 15 feet or more. Flushing and rodding were not satisfactory for removal of this fine sand, serving only to transfer the problem to some other point. Consideration was given to the installation of several grit chambers in the system, but the final arrangement was a portable grit chamber.

This grit chamber is a water-proofed wooden box 3 by 14 feet in plan with a flow depth of 18 inches. The tank is mounted on skids for transportation. Metal plate baffles are placed at the inlet and outlet end. This is set up at a manhole and sand and sewage are pumped into it, the effluent returning to the sewer on the downstream side of a stop plank in the manhole. The sewer line between this manhole and the next above is "dragged" to bring the sand to the suction of the gasoline driven diaphragm pump which supplies sewage to the grit chamber. Grit, which is removed manually from the chamber, is treated with chloride of lime and stored temporarily on the ground prior to removal. During the past summer 20 cu. yds. of sand have been removed from 2100 feet of 12, 15 and 18 inch sewers.

The cost of the grit chamber complete was $75 and about $50 was spent for rope, pulleys and miscellaneous equipment. The pump, which was already available, has a capacity of 20 to 25 gallons per minute.

The daily cost of operation averaged about $35, including the services of four men and a charge of $8.00 per day for the use of horses to operate the drag line.

R. S. Smith

CHLORINATION OF SEWAGE

By Willem Rudolfs

Water Works and Sewerage (October, 1934)

Recent studies show that efficiency of chlorine added to sewage is affected by a number of factors. Under certain conditions, considerable saving of chlorine may be effected, or the efficiency of the chlorination process may be increased without additional cost. Until recently it has been assumed that to obtain a substantial reduction of total bacteria and B. coli the sewage should be completely chlorinated and preferably show a chlorine residual. Experimental results given show that with a 7.5 minute contact period and but 60 per cent of the chlorine demand satisfied, the reduction in total bacteria and B. coli were 95 and 85 per cent respectively. Bacterial reductions increase not only with the chlorine dosage but with the time of contact. For example, to secure a 90 per cent bacterial kill requires but 2.5 minutes with 100 per cent of the chlorine demand satisfied, but the same result may be obtained with but 35 per cent of the chlorine demand satisfied if the contact period is 30 minutes.

Various substances that may be present in sewage may interfere with the action of chlorine. Carbonaceous substances in solution or suspension have practically no effect but nitrogenous substances have a large chlorine demand. It is more difficult to secure the desired kill of organisms in stale than in fresh sewage. With a septic tank effluent it may be impossible to secure high kill unless a sufficient quantity of residual chlorine is present.

Experiments have shown that a high percentage of the applied chlorine is absorbed immediately and most of the kill is nearly instantaneous. For this reason, the efficiency of the initial distribution of the chlorine is one of the most important factors in procuring efficient, economical results. Distribution by means of nozzles or forced sprays would undoubtedly save chlorine.

Partial chlorination may be successfully used in many cases, such as when sewage is discharged into large volumes of diluting water or for odor reduction in sewers. In such cases, efficient distribution and sufficient contact time are essential in producing satisfactory results.

R. S. Smith

SLUDGE GAS AT TOLEDO PLANT COULD OPERATE PUMPING STATION

By A. H. Niles

Engineering News-Record, p. 626 (November 15, 1934)

In the treatment works as designed, no provision was made for utilizing gas from sludge digestion other than to heat the digesters and buildings, as it was intended to use the excess gas for a new garbage incineration plant then in prospect. In 1933 the total volume of gas collected amounted to over 67 mil. cu. ft., of which 24 mil. cu. ft. were used for heating purposes and 43 mil. cu. ft. were wasted.

The possibility of using this excess gas for generating all of the electric current used at the Bay View Park pumping station and at the treatment works is being studied, as the current now purchased costs about $20,000 per year.

The gas from analysis shows an average net heat value of 650 B.t.u. per cubic foot. By using in part figures presented by Walraven of Springfield, Illinois, a basic figure of 1 h.p. hour from 10,000 B.t.u. of gas has been established. It would, therefore, take 15.4 cu. ft. of the gas to produce 1 B.h.p. hour, or 20.6 cu. ft. to produce 1 kw. hour with 100 per cent efficiency. Assuming a 20 per cent loss, this figures to 25.75 cu. ft. of gas per kw. hour on the switchboard. The current requirements were balanced against the number of kilowatt hours of gas "available for power" produced. Any excess or deficiency over requirements for power was reduced back to cubic feet, which fixed the size of a holder at 200,000 cu. ft. capacity.

H. W. STREETER

CANNERY WASTE TREATMENT IN WISCONSIN

By L. F. Warrick

Water Works and Sewerage (October, 1934)

Because of their strength and chemical characteristics, the discharge of untreated cannery wastes into public sewerage systems has caused difficulties at treatment plants and their direct discharge into water courses, serious nuisance.

During the season of 1926 co-operative research by the Wisconsin Canners' Association and the Wisconsin State Board of Health indicated that the oxygen demand of pea canning wastes could be reduced 75 per cent by fine screening and chemical treatment, using ferrous sulphate and hydrated lime. As a result of these studies, treatment plants of both continuous-flow and fill-and-draw type were installed at several canneries during 1927. Operating results indicated that the fill-and-draw system gave more satisfactory results. Screening of the wastes is the first step and is essential regardless of what further treatment is adopted. The most effective results are obtained with mechanical rotary screens having at least a 40-mesh wire covering.

During 1928 operating results at eleven plants treating cannery wastes by chemical precipitation indicated that the oxygen demand of these wastes was reduced from 50 to 75 per cent by the application of 3¼ pounds of ferrous sulphate and 7¼ pounds of lime per 1,000 gallons of pea canning wastes; 2¼ pounds of ferrous sulphate and 6 pounds of lime per 1,000 gallons of wax bean wastes; and 3¼ pounds of ferrous sulphate and 6 pounds of lime per 1,000 gallons of corn wastes. Experience showed that thorough mixing of the chemicals with the waste and a settling period of at least one hour are required and that daily removal of the sludge is essential. Treatment of pea wastes cost 0.34 to 0.78 cents per case of No. 2 cans, including cost of chemicals, labor and disposal of the sludge. The cost of a plant for the treatment of wastes from a three line pea cannery was $3,500.

Studies of treatment of pea cannery wastes by use of a trickling filter, both with and without chemical precipitation before filtration, were started in 1928. Initial studies indicated that in treating pea cannery wastes, a trickling filter would reduce the remaining oxygen demand after chemical precipitation, from 35 to 84 per cent if the wastes were applied at a rate not in excess of three million gallons per acre per day. In 1929 an attempt was made to seed the filter by passing a manurial infusion through it for several days before the start of canning. Results indicated that with this method of seeding for five days in advance of the canning season, from 10 to 14 days are required after the start of the pack to reach a fair operating efficiency. In 1930 a different method of seeding was tried. Material sloughed from a municipal trickling filter was applied twice daily for four successive days, starting one week prior to the pack. The filter was wet at least twice each day with a sugar solution, using about ¼ pound of sugar per square foot per day. Results indicated that by the use of this seeding procedure the efficiency of a trickling filter may be established before canning starts.

Development work on cannery wastes includes many special projects, such as the elimination of silage juice seeping from pea vine stacks, by cutting and drying the vines as they leave the vine station. By this means the substances wasted in silage juice can be retained in the stock food produced. Unless dryer facilities are provided it is necessary to convey the juice to some isolated site for disposal by soil absorption. Fly and odor nuisances around the stack must be minimized by the application of lime and deodorants.

R. S. Smith

NOTES ON SEWAGE TREATMENT AND TRADE WASTES

Public Works, Vol. 65, No. 10, 30 (October, 1934)

In planning for sewering the Annapolis Maryland Metropolitan area, difficulty was anticipated due to the use of salt water for flushing purposes at the U. S. Naval Academy. The sea water gives a high sulfate and chloride content to the sewage with consequent production of hydrogen sulfide and retardation of the rate of settling of the sewage solids. The use of chlorine has been recommended to prevent the production of hydrogen sulfide. Chlorination to a residual of 1 p.p.m. has been found to increase settling rates.

A summary of the data on distillery wastes collected by the Ohio State Board of Health and the U. S. Geological Survey some years ago, is as follows:

From the still and rectifier, 45 gallons of waste per bushel of grain are produced with a total solids content of 50,000 p.p.m. Ten per cent of the solids can be recovered at a profit by screening, and an additional 50 per cent disposed of economically as a liquid cattle food. Complete recovery by evaporation is economically practicable in any but the smallest plants.

R. W. Kehr

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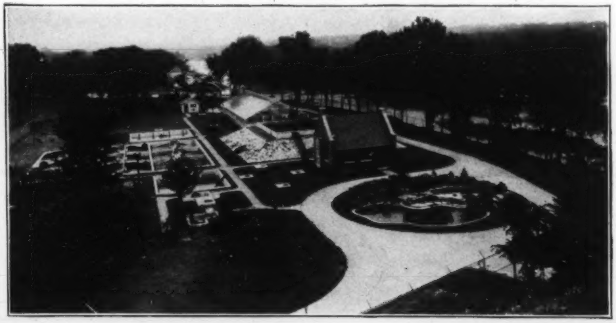

The PFT floating cover used in the square digester lends itself well to the attractive landscaping plan of this modern treatment plant on the bank of the Fox River. Concrete walkways, rip rap on the digester slopes, glass covered sludge beds, etc., as well as the natural beauty of the site, contribute to a pleasing picture. The visitor upon entering the grounds is greeted by a view of the rock garden and pool.

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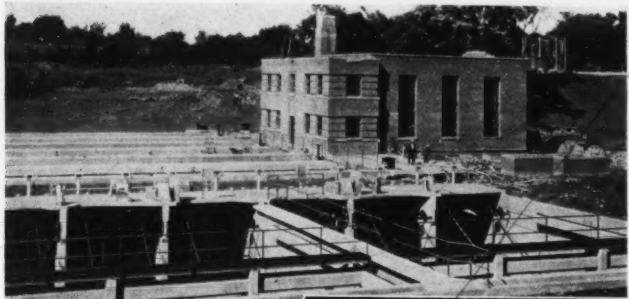

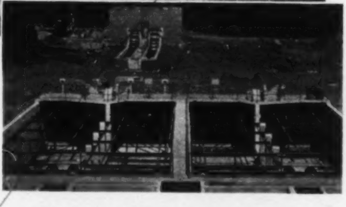

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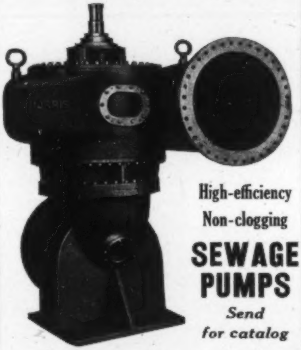

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